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Two Recent Developments in Car Ventilation.

Every year the question of car ventilation comes up more or less prominently about the commencement of the cold season, and this applies to both steam railways and electric railways. As far as electric interurban railways are concerned the conditions are very much the same as for steam railways, but on city street railways (and elevated lines) the conditions are such as to form a special and difficult problem, due to the frequent opening of the doors. The street and elevated railways of Chicago are now considering some improved methods of ventilating, and one of these (which is being applied to a number of street cars) is described below. We give also some particulars of a recent improvement in the ventilation of sleeping cars.

A New Ventilating System for Street Cars.

The introduction of the vestibuled type of car in street railway service, has improved the conditions for providing proper heating and ventilation of street cars, by eliminating the wide end doors and exposed platforms of the older types of cars. The Health Department of Chicago has for some time been conducting investigations as to methods of improved ventilation in the street cars of that city, and has approved the application of a new system to 350 cars which will be put in service by the Chicago Railways Co. during the winter. The cars are of the prepayment type, the arrangement of which is such as to prevent the entrance of large volumes of cold air at the doors. At the rear of the car is a large vestibuled platform, open on one side only and with a narrow swinging door at the closed side for entrance to the body of the car. Another swinging door for exit is used only when the car is coming to a stop. At the front end is a vestibule connecting with the interior by a swinging door, and having a side door for exit only. This side door is normally closed, and is under the control of the motorman, who opens it when the car has come to a stop but only if a passenger wishes to alight. The swinging doors obviate the trouble from careless passengers who do not trouble to close doors behind them. The general design of these cars, with the ventilating equipment, is shown in Fig. 2.

The method of ventilation is on the vacuum or induced-draft system, the vitiated air being drawn off by a fan and causing the entrance of fresh air to take its place. The headlining of the monitor roof is placed about 4½ ins. below the carlines, forming a chamber between the roof and the headlining. The sides of the chamber are sloped up at 45° to the corners of the roof so as not to interfere with the operation of the hinged deck windows. There are 14 registers about 6 ins. diameter, with adjustable gratings, placed at intervals in the ceiling; they project upwards 2 ins. into the air chamber. Each vestibule has a rectangular register in the ceiling, connected to the roof air chamber by a duct. In the front end of the monitor roof is a wide opening to a conical duct leading to a 10-in. exhaust fan driven by an electric motor of ¼-HP. The fan and motor are mounted on the vestibule hood and are enclosed in a sheet copper housing, with lateral discharge openings. The fan is under the control of the motorman, but it operates at uniform speed. On this page is an interior view of a car equipped with this system, showing the registers in the ceiling.

INTERIOR VIEW OF STREET CAR FITTED WITH THE COOKE VACUUM VENTILATING SYSTEM.

(The circular registers in the headlining open into a chamber between the headlining and roof, which chamber is in communication with an exhaust fan.)

The fresh air intakes are metal ducts fitted under the seats, as shown in Fig. 3. Each has a screened bottom opening 4 × 7 ins. in the floor of the car, and a larger upper opening directly beneath an electric heater, so that the entering air is passed over the heater coils before being diffused through the car. Each duct is of 1/16-in. pressed steel, made in two parts with an electrically welded seam; the top and bottom collars are riveted in place. After assemblage, the completed duct is treated with zinc by the Sherardizing process so as to give it a non-corrosive surface. There are eight of these ducts, weighing only 6 lbs. each.

The areas of the intake and exhaust openings are proportioned to permit of the passage of air at a low velocity (approximately 325 ft. per min.), so that there will be no perceptible draft. The rate of flow of the air is dependent upon the speed of the fan, and is not affected by the movement of the car. It is stated that expensive experiments have shown that the amount of air handled by this system remains practically constant, whether the car is at rest or in motion. The system is adaptable to other types of cars than that mentioned. It is the invention of Mr. D. I. Cooke, Secretary and Chief Engineer of the Vacuum Car Ventilating Co., Fisher Building, Chicago, to whom we are indebted for information.

Ventilation of Sleeping Car Berths and Dining Car Refrigerator Boxes.

The ventilation of the lower berths of sleeping cars is usually very inadequate, as each berth is completely enclosed when the upper berth is made up and the curtains are hung. Few passengers care to have the window open during the night, even if the weather is mild, for the entrance of dust and dirt (in spite of the wire screens) is such a nuisance that a closed window is preferred. The upper berths, being partly open to the monitor deck, are readily ventilated by any good system of general ventilation, but the lower berths are closed individual cells. A recent improvement in car ventilation is its application to the individual lower berths of sleeping cars, and also to the ice boxes of dining cars.

This is a development of the Garland system of car ventilation, which has been in extensive use on sleeping and dining cars, refrigerator cars, etc., for some time. It is an induced-draft system, depending upon the current caused by the movement of the car, and the principle of its operation is shown clearly by the diagram in Fig. 4. The air forced into the funnel-shaped hood as the car moves forward is diverted laterally and escapes as a jet which induces a cur-

rent in a channel opening into the car. The hoods are placed on the sides of the roof, with openings through the walls of the monitor deck. Through these openings the air at the top of the car is exhausted. The new development consists in making the ventilator double (as shown in Fig. 5), the upper half being connected to the deck opening while the lower half communicates with the lower berth (or dining car refrigerator) by means of a flat duct. The ventilating system and its new application are the invention of Mr. Thomas H. Garland, of Chicago, General Agent of the Refrigerator Service of the Chicago, Burlington & Quincy Ry., who has furnished us with plans and other information.

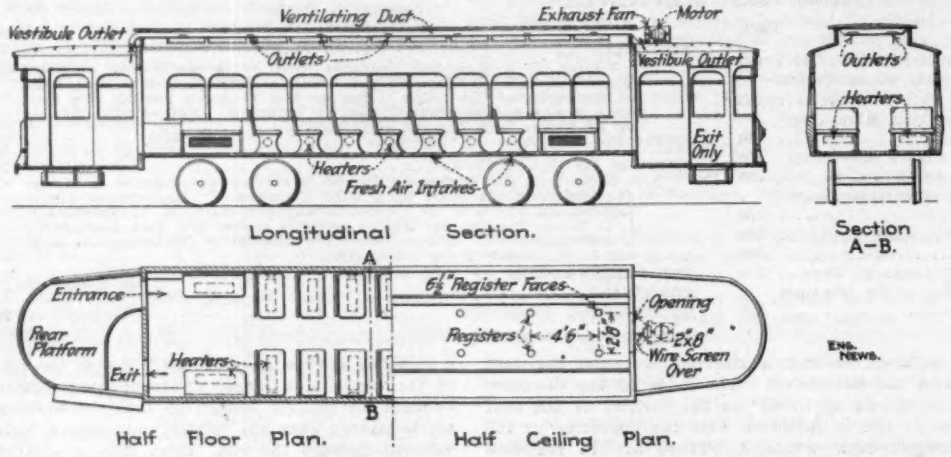


FIG. 2. STREET CAR OF THE PREPAYMENT TYPE FITTED WITH THE COOKE VACUUM VENTILATING SYSTEM; CHICAGO RAILWAYS CO.
D. 1. Cooke, Inventor; Chicago.

Comparison of Forced-Circulation Hot-Water, and Vacuum Steam Central Heating Plants.

By JOSEPH T. MAGUIRE.*

The writer, in a paper published in Engineering News, Sept. 2, 1909, outlined the principal features in the design of a large central heating plant for the forced circulation of hot water. In that article the writer merely mentioned the primary considerations which would lead to the proper selection of a system. These were, (1) first cost, (2) operating expenses, (3) flexibility and cost of additions, (4) degree of possible centralization of working parts. In the present article the first three of these points are discussed in the hope of demonstrating to engineers, whose experience has largely been along other lines, but who have occasional need of approaching these problems, that the large hot-water plant is usually preferable to the vacuum steam. The writer has found the contrary idea to be generally prevalent among engineers and laymen alike. It is sufficient to point out a general way, with specific application, of making a proper comparison of these two systems.

It is necessary first to review briefly the operation of the two systems. In the hot-water plant, at a selected average minimum outside temperature, the water is circulated by a pump at 212° F., through outflow pipes to the radiators and through return pipes to the heater. When the outside temperatures are higher or lower than the selected minimum, then the hot-water is circulated at lower or higher temperature respectively and the plant, one may say, is under or overloaded. This was explained more in detail in the article of Sept. 2.

In a vacuum steam system, exhaust steam is drawn through the pipes and radiators at about, or slightly above, atmospheric pressure, for all outside temperatures. Consequently the heating medium is always at or above 212° F. This fact alone has a great effect on the losses and operating cost as will be shown later. The pumps in the vacuum-steam system are in the return system and have to handle hot water, air and steam successively.

The heaters for the hot-water system are cylindrical steel shells with dished heads bolted on and with iron tubes expanded into steel plate partitions. Exhaust or live steam is admitted around the tubes while the water flows through them.

The relative merits of the two systems as regards ease of operation and quality of heating effects, will not be discussed here as these are the result of the designer's ability and personality. The relative costs, however, can be easily calculated.

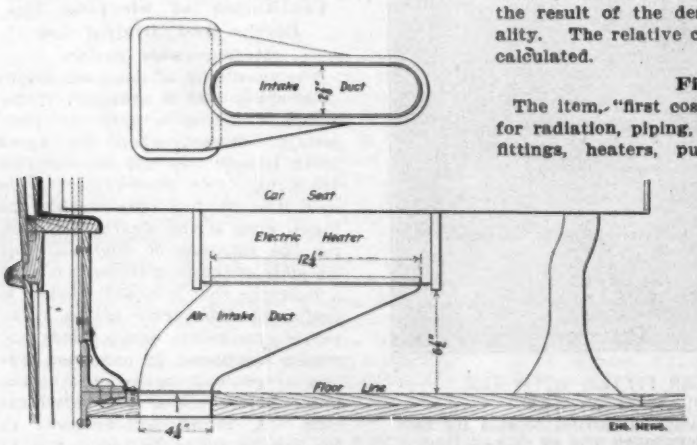


FIG. 3. INTAKE DUCT FQR COOKE VACUUM CAR VENTILATING SYSTEM.

*Designer, Bureau Yards and Docks, Navy Department, Washington, D. C.

First Cost.

The item, "first cost," includes all expenditures for radiation, piping, insulation, conduits, valves, fittings, heaters, pumps and other apparatus necessary to place either installation in complete working order.

As explained in the earlier article, the total amount of radiating surface in the buildings is identical for both systems. In this respect the two are on a par.

The items of "piping," "valves" and "fittings" for convenience, should be studied in two parts: (1) apparatus and piping within individual buildings, and (2) the installation between building and central plant and at the latter. Table I. shows the comparison of unit costs of materials for a single building having 2,000 sq. ft. of radiating surface. Labor costs are assumed to be proportional to the costs of material, an approximately correct assumption. This table shows that the cost of steam fitting on the interior is about 90% that of the hot water. The sizes of pipes shown are of those usually employed in gravity-flow, hot-water and exhaust-steam house installation. In the hot-water design the sizes are for velocity of about 2 ft. per sec.

In taking up the piping from the individual buildings to the central plant, it is convenient to assume two installations of 16,000 and 90,000 sq. ft. of radiating surface supplied by the station, as minimum and maximum sizes of such central-heating installations. The sizes of pipes for these two systems are as follows:

	Steam.	Hot water.
16,000-sq. ft. installation.	8-in. flow 2-in. return	4-in. flow 4-in. return
90,000-sq. ft. installation.	18-in. flow, or 2—12-in. flows 3½-in. return	9-in. flow 9-in. return

The sizes of hot-water pipes, here given, are calculated by standard practice as outlined in the article printed in Engineering News Sept. 2, and using a water velocity of 8 ft. per sec. The velocity of steam in the flow lines of the vacuum-steam system is assumed at 100 ft. per sec. Unit costs for these outside lines are compared in Table II.

An examination of Table II. shows that the hot-water installation is cheaper in each item, except in the matter of elbows and, in the smaller installation, the additional item of tees. The reason for the larger cost of these items, in the hot-water system, lies in the adoption of long-turn fittings in order to minimize the frictional resistance.

When we consider that in a properly designed system, all branches are valved, to allow of a shut-down of the branch without interfering with the rest of the system, and that, in consequence, there is always a valve wherever there is a T-fitting, we arrive at the conclusion that a fair estimate of the outside piping-valves, etc., cost may be quickly made by simply comparing the costs of piping, allowing the cost of elbows to offset the differences between the two systems in regard to valves and tees. Such a comparison favors steam, if anything, as will be seen by examining the prices given and by considering the fact that the number of elbows in any system is exceedingly small, and, therefore, the total cost of them, in comparison to the cost of the entire installation, is almost negligible.

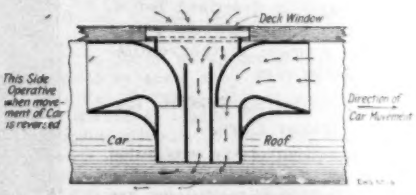


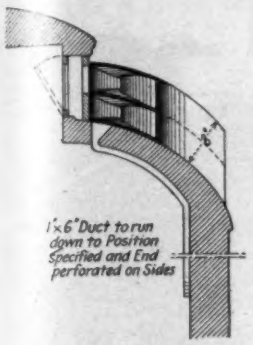
Fig. 4. Diagram Showing the Operation of the Garland Induced-Draft Ventilating System as Applied to Sleeping Cars, Refrigerator Cars, Etc.
Thomas H. Garland, Inventor; Chicago.

A study of Table II. shows that the vacuum-steam outside lines cost (unit prices) 160% and 67% more than for the hot-water system in the larger installation, depending on whether a single 18-in. flow line or two 12-in. flows be used. In the smaller installation the excess first cost in the steam system is 36%.

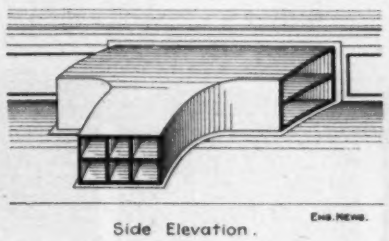
Costs of installations of magnitudes between the two systems studied here will be proportionate to these figures. The price of pipe-covering will also show, approximately, the same discrepancy between the two systems. Prices for the latter have been omitted as there are very many different types on the market, of various efficiencies and of widely varying prices. The relative costs of conduit for the two systems has also been omitted, but may be considered as nearly equal for the two systems, the total lengths being the same, and the cross sectional area being nearly the same. The balance, however, would be in favor of hot-water.

It is well to note that the popular idea that more valves are required for a hot-water system than for the vacuum steam is absolutely fallacious. Even supposing that the frictional resistance of a hot-water system was balanced by a manifold, with valves, in each branch, the cost ratios are not appreciably changed, as the sizes

of the valves for a hot-water system are smaller than for the vacuum-steam and the costs are decreased in still greater proportion than the sizes. The vacuum-steam radiators always have two valves, one a gate valve on the supply, and a thermostatic valve on the return.

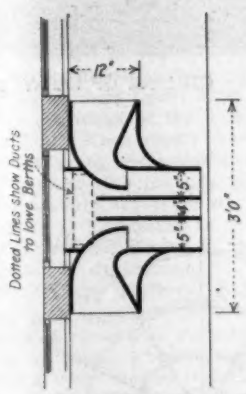


End Elevation.



Side Elevation.

Fig. 5. The Garland Ventilating System Arranged with Separate Ducts to the Lower Berths of Sleeping Cars.



Sectional Plan.

The only point remaining to be considered, in connection with the item of first cost, is the central station installation. In the hot-water system this comprises the pumps, engines or motors, heaters and the expansion tanks. In the vacuum-steam system it comprises the vacuum pumps.

If the exhaust steam indirectly heats the water for the forced circulation water system, there would be no change in plans for the boiler capacity of the plant. The same amounts of radiation are to be supplied and about the same amounts of power are required for operating the pumps of either system. If there is any advantage in this respect it lies in favor of the hot-water system on account of more favorable and economical conditions for pumping, as stated earlier. The item "pumps" has been pluralized for both systems as the writer believes that provision for safe service in time of break down should be made. Two pumps, each of a capacity of two-thirds the maximum requirement would be approved. This also has the great advantage of running only one pump in time of a light heating load, thereby operating at maximum economy.

It is seen that in a hot-water plant there must be the added investment for the heaters, expansion tanks and a few added valves. But as the heaters are simple shells with lap welded tubes and of standard materials of a non-proprietary nature, this is not serious, and the extra cost cannot offset the gain from the outside piping, unless the outside runs are very short. If the buildings to be heated are grouped around the central heating station in such a way as to minimize the lengths of runs of outside piping, the vacuum steam system would undoubtedly, be cheaper, but, in ordinary installations, where the cost of the outside piping is nearly equal to or greater than the cost of the piping within buildings, the hot-water system would require the smaller investment.

TABLE I.—COMPARISON OF UNIT FIRST COSTS OF VACUUM-STEAM AND FORCED-CIRCULATION HOT-WATER HEATING SYSTEMS. INTERIOR WORK.

STEAM.	
Pipe:	
1 ft., 4-in. iron pipe	$0.33
1 ft., 1½-in. iron pipe	0.08
Total	$0.41
Valves:	
1—4-in. (low pressure)	6.00
1—1½-in.	1.50
Total	$7.50
Tees:	
1—4-in.	0.70
1—1½-in.	0.12
Total	$0.82
Elbows:	
1—4-in.	0.48
1—1½-in.	0.08
Total	$0.56
WATER.	
Pipe, 2 ft., 3-in. iron pipe, at 23 cts.	$0.46
Valves, 2—3-in., at $4.50	9.00
Tees, 2—3-in., at 44 cts.	0.88
Elbows, 2—3-in., at 30 cts.	0.60

Operating Expense.

With the best insulation available, on a system of ordinarily large mains, the radiation loss is approximately 10% that supplied to the radiating surface. In the vacuum-steam system this loss is constant, at about 10% the total heat supplied in the radiators, as the mains are approximately constant temperature irrespective of outside temperature conditions. In the hot-water system the radiation loss is at a maximum in the severest weather when the water is circulated at the highest temperature. As the need for heat diminishes the temperature of the water circulated is decreased and with it the radiation loss. Even at times of maximum loss the wasted radiation from the steam lines is greater than from the hot water. The radiation loss per square foot of superficial area is the same in either case, of course, but the total area per lineal foot of steam line is greater than in the case of the hot-water lines. For instance, take the 90,000-sq. ft. installation mentioned before:

Area, 1 ft. 18-in. iron pipe (18 ins. o. d.)	4.71 sq. ft.
1 ft. 3½-in. iron pipe (4 ins. o. d.)	1.05 " "
Total	5.76 " "
Area, 2 ft. 12-in. iron pipe (12.75 ins. o. d.)	6.68 " "
1 ft. 3½-in. iron pipe	1.05 " "
Total	7.73 " "
Area, 2 ft. 9-in. pipe (9.68 ins. o. d.)	5.06 " "

It is evident that the maximum radiation loss on the vacuum-steam system is from 14 to 53% greater than for an equivalent hot-water system.

In a specific investigation, along the lines herein only generally laid down, the study of operating expense should include that of the central plant. The principal item here is in the pumping. Each specific installation has its own peculiar conditions so that a wholly general comparison is impossible in this article. The writer is content with giving results in an actual case where a design was made, on both systems, for a total radiating surface slightly in excess of 16,000 sq. ft. The vacuum pump required was a 5 × 5¾ × 5-in. duplex type. The average steam consumption was estimated to be 945 lbs. The actual installation, however, was made for hot water and a centrifugal circulating pump was driven by a 25-HP. motor. Had this been driven by a small steam engine the probable steam consumption at full load, corresponding to severe weather would have been only 750 lbs. per hr. The gain in pumping in this case, it is fair to assume, was about 20%.

While the pump in the vacuum-steam system handles approximately 1/32 the amount of water circulated in the hot-water system (each pound of steam gives off 960 B. T. U., compared with 30 B. T. U. per lb. of hot water circulated), it works against unbalanced lifts, heavier pressure and mixtures of air, steam and water.

TABLE II.—COMPARISON OF UNIT FIRST COSTS OF VACUUM-STEAM AND FORCED-CIRCULATION HOT-WATER SYSTEMS. EXTERIOR LINES.

STEAM; 16,000-SQ. FT. PLANT.	
Pipes:	
1 ft., 8-in. iron	$0.79
1 ft., 2-in. iron	0.11
Total	$0.90
Valves:	
1—8-in.	20.00
1—2-in.	4.00
Total	$24.00
Tees:	
1—8-in.	8.69
1—2-in.	0.17
Total	$8.86
Elbows:	
1—8-in.	5.94
1—2-in.	0.12
Total	$6.06
HOT-WATER; 16,000-SQ. FT. PLANT.	
Pipes, 2 ft., 4-in. iron, at 33 cts.	$0.66
Valves, 2—4-in., at $8 (medium pressure)	16.00
Tees, 2—4-in., long turn	10.80
Elbows, 2—4-in., long radius	9.25
Total	$36.71
STEAM; 90,000-SQ. FT. PLANT.	
Pipes:	
1 ft., 18-in. iron } or	$4.46
1 ft., 3½-in. iron }	0.27
Total	$4.73
2 ft., 12-in. iron }	2.91
1 ft., 3½-in. iron }	0.27
Total	$3.18
Valves:	
1—18-in. } or	88.80
1—3½-in. }	7.20
Total	$96.00
2—12-in. }	78.00
1—3½-in. }	7.20
Total	$85.20
Elbows:	
1—18-in. } or	29.50
1—3½-in. }	1.94
Total	$31.44
2—12-in. }	25.00
1—3½-in. }	1.94
Total	$26.94
Tees:	
1—18-in. } or	42.50
1—3½-in. }	2.81
Total	$45.31
2—12-in. }	36.50
1—3½-in. }	2.81
Total	$39.31
HOT-WATER; 90,000-SQ. FT. PLANT.	
Pipes, 2 ft., 9-in. iron	$1.90
Valves, 2—9-in.	48.00
Elbows, 2—9-in., long radius	30.00
Tees, 2—9-in., long turn	35.00

Without the use of an expensive thermostatic control on the vacuum-steam system, the radiators are at a temperature of 212° F. whenever in use, at all conditions of weather. Consequently heat is wasted in such an installation, in addition to the losses along the pipe lines. This can be avoided with hot water. Such a waste, however, becomes really important only when the exhaust steam is not abundant and is useful for other industrial purposes or when there is never need of blowing live steam into the exhaust lines or the water heater. In all such cases each economy in operation becomes important.

In a paper of this kind, dealing with generalities largely, actual stated percentages should not be held too conclusive in themselves but rather as quantitatively indicating tendencies. The points here discussed should indicate the lines of investigation to be followed by any engineer in seeking the best design for a given situation.

In the great majority of cases, intelligent study will show that the vacuum-steam is some 10% cheaper in interior pipes and fittings and about 5% cheaper in central-station fittings. In the cost of radiators, future extensions, conduits, there is no great advantage of one system over the other. But in the cost of outside pipe lines, there is a saving of some 50% with the hot-water plant, and in operating expenses this system is anywhere from 15% upward more economical than the vacuum-steam.

A Flat Slab Reinforced-Concrete Street Railway Bridge, St. Paul, Minn

The accompanying half-tone and drawings illustrate a bridge in which the girderless flat-slab or "mushroom" system of reinforced concrete has been applied. Until recently this type of construction has been used exclusively for buildings, and in such use has been described in these columns. This St. Paul bridge is, however, the first instance where we have had occasion to illustrate the application to bridges.

The bridge shown carries the two-track line of the Twin City Rapid Transit Co. over the tracks of the Minneapolis, St. Paul & Sault Ste. Marie Ry. on the line of Lafayette Ave. in St. Paul, Minn. One abutment is on a skew so that the span increases from 76 ft. 6 ins. at one side to 91 ft. 9 ins. on the other. The width is 66 ft. made up of a 42-ft. roadway and two 12-ft. sidewalks. This whole floor is supported by two L-shaped reinforced-concrete abutments and six mushroom-topped columns, the latter spaced 37 and 27 ft. in the two directions, as shown in Fig. 2.

The columns are about 24 ft. long and 30 ins. in diameter, and are reinforced with eight 1⅛-in. round vertical bars, which bend into the 13-ft. mushroom head and the spread base. In addition the head has two cross bars of 1⅛-in. steel (Fig. 3). The slab reinforcement is of ⅝-in. round steel. In order to get the crown required by city regulations the slab was made 24 ins. thick at the middle, sloping down to a 15-in. thickness at the gutter. By the use of hollow tile blocks the sidewalk is raised 8 ins. above the gutter. The track is carried on Carnegie steel ties embedded in the concrete and the rest of the roadway is covered creosoted wood block.

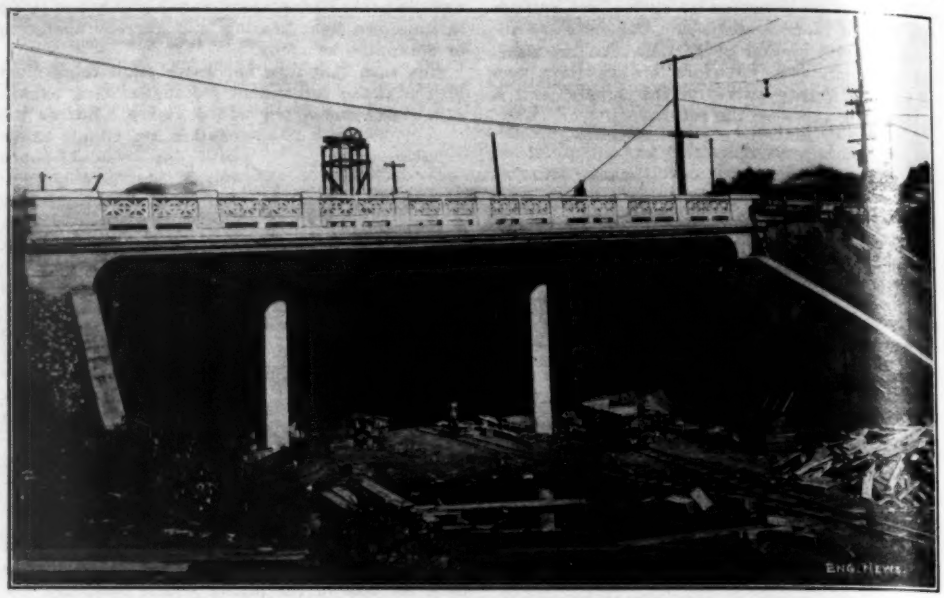


FIG. 1. VIEW OF FLAT SLAB BRIDGE CARRYING STREET RAILWAY ON LINE OF LAFAYETTE AVENUE, ST. PAUL.

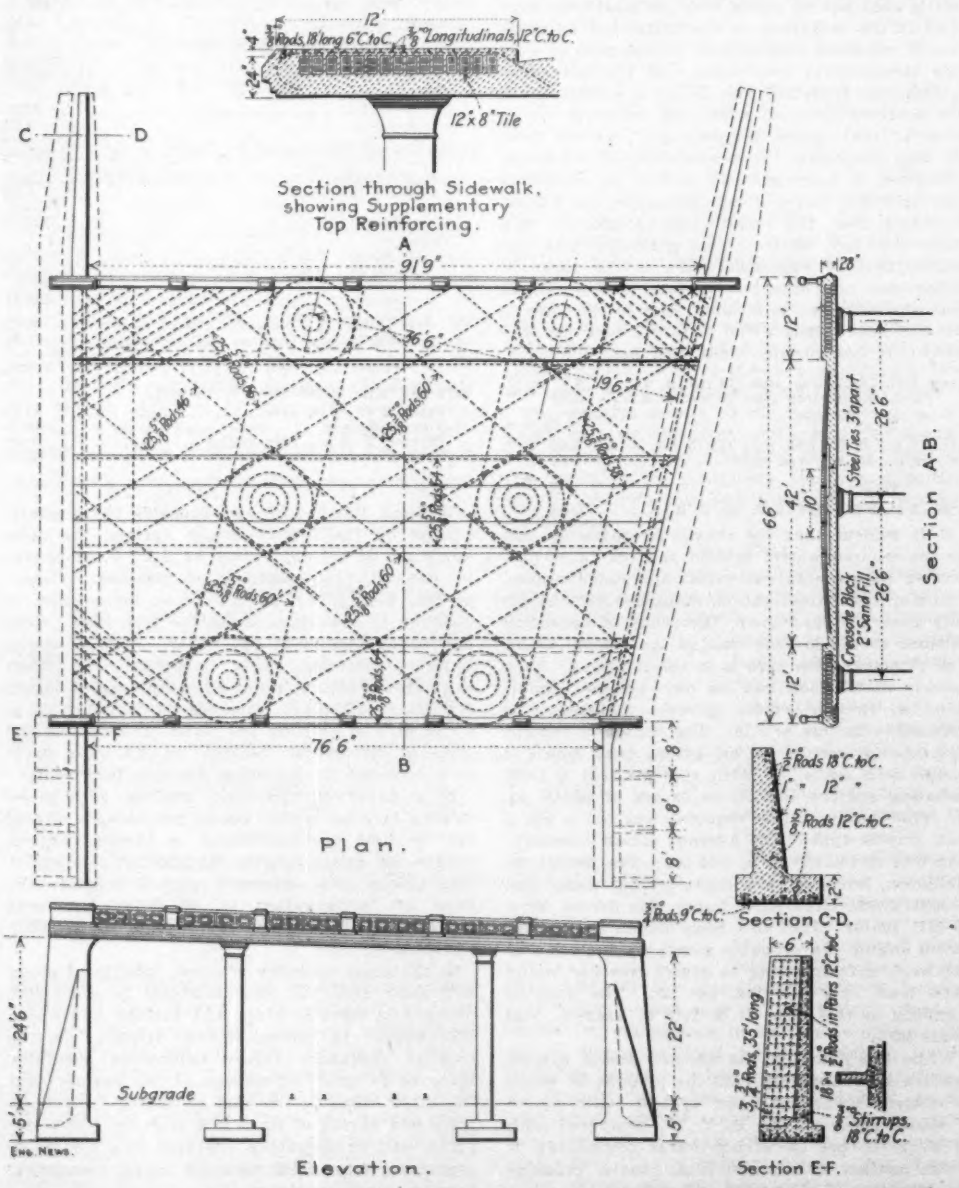


FIG. 2. GENERAL LAYOUT OF LAFAYETTE AVENUE BRIDGE.

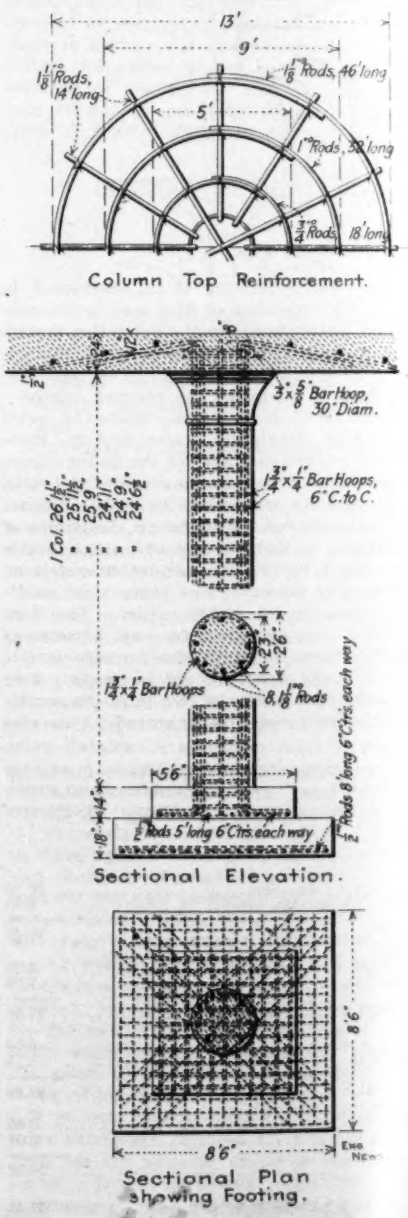


Fig. 3. Column and Slab Details; Lafayette Avenue Bridge, St. Paul.

An ornamental railing of cast concrete stone completes the structure.

In order to maintain traffic during construction the bridge was built in two longitudinal sections In Fig. 1 the centering has been removed from the half in the foreground and concrete laying is going on on the other half.

This is one of several similar structures built in this vicinity; one is now under design with a column spacing of 60 by 34 ft. In addition to an appreciable economy and an increased clearance, it is claimed by the designers that this style of bridge is remarkably rigid. Under the very heavy interurban cars used on this line there is no noticeable vibration.

The Lafayette Ave. bridge was built under the supervision of Mr. Thomas Greene, Chief Engineer of the Minneapolis, St. Paul & Sault Ste. Marie R. R., with Mr. C. A. P. Turner acting as Consulting Engineer. The plans were approved by Mr. L. W. Rundlett, City Engineer of St. Paul, and Mr. G. L. Wilson, Chief Engineer of the Twin City Rapid Transit Co.

Tunnel Failures and Repairs on the Eastern Railway of France.

On railways having a number of old tunnels (especially tunnels in loose or soft material), the engineering department often suffers anxiety as to the conditions of the lining and the material behind it. When repair work is carried out it involves many exceptional difficulties, due to the darkness, the practical impossibility of getting a general survey of the conditions, and the necessity of interfering as little as possible with traffic. Several works of this kind have been described in our columns.*

The Eastern Railway of France has had to carry out extensive repair and reconstruction work on a number of tunnels, and details of this (with the causes which necessitated it) have been given in the "Revue Generale des Chemins de Fer" by Mr. M. Siegler, Chief Engineer of Maintenance of Way. From his paper we take the information given below.

As a result of a collapse in the Montmedy tunnel (noted later) the maintenance department undertook to make an investigation of 58 other tunnels on the line. The first step was to compile all information relative to the original construction work, including notes of the incidents which occurred and of the character of the materials. Much of this information came from inspectors and workmen who had been employed, but whose knowledge would have died with them but for this system of permanent records. In addition to this, the masonry was examined, and in all tunnels through bad ground, test holes were drilled in the arch and walls to determine the thickness of the masonry and the nature or condition of the ground. These long and costly investigations disclosed a number of cases of defective work, and these were repaired. As the drill may be deceptive, through striking the dry rock backing, the results were checked by making larger holes occasionally, by removing one or two blocks of the stone lining. This must be done with caution, especially in soft and wet material, as the holes might be sufficient to start a serious flow of the material.

The restricted dimensions of many of the old tunnels are an important cause of trouble and difficulty in carrying out the repair work. It would be desirable to increase the dimensions when performing the repairs, but this would be useless unless the work was extended over the entire length of the tunnel, which is rarely necessary. In many cases, also the renewal of the arch ring is all that is necessary, in which case it is not practicable to increase the dimensions, except at heavy expense.

The Genevreuille Tunnel.

This is a double-track tunnel, 2,037 ft. long, between Lure and Belfort. It was built in 1855-58, and pierces a ridge which is composed of clay beds with deposits of gypsum. In the moist clay encountered at each end, the masonry lining has a thickness of 3.28 ft. In the hard and dense gypsum rock (through which the greater part of the length lies), the thickness is 20 ins. for the side walls and 32 ins. for the arch. At the middle of the tunnel, crushing of the masonry soon took place, due to the swelling of the gypsum under the influence of moisture. The subgrade (which had no invert) was raised at the rate of 2½ ins. in 10 days. In 1859, longitudinal drains of dry stone were laid beneath the subgrade. An invert was also built for a length of 1,115 ft., with a thickness of 24 to 36 ins. at the center and 3½ to 5 ft. at the sides, and with a drain underneath. At the same time, the damaged side walls were rebuilt. On the completion of the invert, more serious troubles began to appear. The side walls, held at the bottom by the invert and at the top by the roof, were unable to resist the enormous pressure, and threatened to burst inwards. A cut was promptly made in the invert, to allow the base of the walls to move inward.

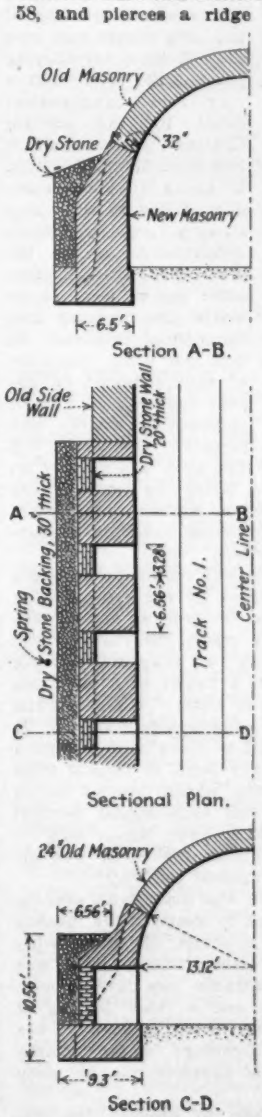


Fig. 1. Reconstruction of the Genevreuille Tunnel in Swelling Ground.

As the pressure could not be resisted, all that was attempted was to prevent the swelling as much as possible by draining the tunnel. For this purpose, in 1860 a gallery was commenced 26.24 ft. below the tunnel. This is 32 ins. wide and 5 ft. high, with a length of 3,770 ft., and a grade of 0.04%. It was driven from shafts sunk through the subgrade, and some of these were maintained permanently to facilitate the maintenance or repair of the gallery. Under the tunnel, the gallery is timbered, but under the approach cut it is lined with masonry. From this main gallery extend ten smaller drifts, some lateral and others longitudinal, to facilitate the drainage of the very wet spots. A number of holes discharge water from the subgrade into the main gallery, and these are cleaned periodically. The galleries improve the ventilation, as well as provide for drainage.

The timbers supporting the walls of the gallery yielded gradually under the pressure, crushing occasionally and being renewed as required. The material was then excavated to maintain the normal width. It was necessary to fit the caps on the posts without notches or tenons, as otherwise the caps would be broken in a short time. The swelling of the gypsum did not cease entirely, and the side walls of the tunnel continued to move inward and to crush at certain points. Every year it was necessary to rebuild a part of the walls, either to prevent a collapse or to restore the full width of the tunnel. The masonry was built thicker and of harder material, but without stopping the movement.

In 1886, a different system was tried, the continuous side walls were replaced by a series of vertical piers 6.56 ft. square, and 3.28 ft. apart. The spaces between them had each a 20-in. vertical wall of dry stone in the rear portion, and behind the piers and dry walls was placed a dry stone backing of variable thickness. This construction is shown in Fig. 1. As the thrust of the swelling material is exerted, it simply presses the dry stone forward into the recesses; when necessary, this is removed, the material excavated, and the dry stone backing and wall rebuilt. This work was completed in 1894, and since that time the side walls have required very little repair.

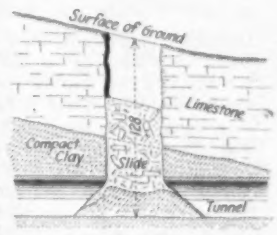


Fig. 2. Vertical Fall in the Montmedy Tunnel.

In 1903, a new trouble appeared. At that part of the Belfort end where the tunnel is in clay, the ground began to move and to push in the base of the sidewalls. This may have been due to the clay itself or to the gypsum embedded in it. It was important that the movement should be checked, and it was decided that the pressure might be resisted. The walls were strongly braced at the bottom by means of heavy pine timbers placed under the track, and as soon as possible a 24-in. invert was built of masonry in cement. Up to the present time no further signs of movement have appeared.

The Montmedy Tunnel.

This is a double-track tunnel, 2,647 ft. in length, which was built in 1859-63. It pierces the mountain on which is built the fort of Montmedy; the upper part of the mountain is of oolitic limestone, much fissured and broken, while the lower part is of compact clay. The tunnel is entirely in the latter. The e is a great quantity of water in the limestone, and the construction work was stopped several times by the inrush of water. To carry off this water, a lateral gallery was built, and was to have been lined throughout with masonry, but it caused such movements of the ground that the upper end was filled solid with rubble stone. From this gallery ran others to tap the most important sources of the water which had stopped work in the tunnel. This work presented many difficulties. At several points the roof of the tunnel was crushed or deformed by the pressure of the clay; here the roof was rebuilt, only to be crushed again and rebuilt a second time.

Five years after the completion of the tunnel it was observed that the gallery was choked with sand and that the water was penetrating the masonry lining of the tunnel. In 1870 (at the time of the Franco-Prussian war), the ends of

*The following notes of former articles on tunnel repair work may be found useful:

Converting a Tunnel into an Open Cut; Caledonian Railway, Scotland. April 21, 1892.

Converting a Tunnel into an Open Cut; Norfolk & Western Ry. Aug. 4, 1904.

Repairing Slides in the Big Bull Tunnel; Norfolk & Western Ry. June 9, 1892.

Building Masonry to Replace Timber Lining in the Boulder Tunnel; Great Northern Ry. Oct, 12, 1893.

Enlarging a Narraw-Gage Tunnel for Conversion to Standard Gage; B., R. B. & L. Ry. Dec. 6, 1894.

Stopping a Landslide in the Wight's Tunnel; Southern Pacific Ry. Nov. 28, 1895.

Repairing a Tunnel on the Western & Atlantic Ry. Jan. 23, 1899.

Relining a Timbered Tunnel with Masonry; Norfolk & Western Ry. March 22, 1900.

Rebuilding a Damaged Portion of the Ronco Tunnel (Italy). April 19, 1900.

Roof Timbering in a Rock Tunnel; Norfolk & Western Ry. April 19, 1900.

Lining the Musconetcong Tunnel (L. V. Ry.) Without Interrupting Traffic. Nov. 7, 1901.

The Aspen Tunnel; Union Pacific Ry. (Built in Swelling Shale). March 6, 1902.

Driving a Tunnel Through Caving Material in France. Sept. 11, 1902.

Changing Grade and Building Lining in a Tunnel under Traffic; Chicago Great Western Ry. Aug. 4, 1904.

Caving of the Gunnison Tunnel. June 29, 1905.

Lowering the Chicago River Tunnels. Sept. 13, 1906; March 7, 1907.

Tunnels in Sliding Ground (France and Switzerland). Sept. 13, 1906.

Grouting a Leaky Tunnel in France. Oct. 11, 1906.

Lining the Hodges Pass Tunnel with Brick and Concrete to Replace Timbering; O. S. L. Ry. Dec 6, 1906.

Tunneling in Plastic Clay; Canadian Pacific Ry. April 18, 1907.

Grade Correction and Reinforcements by Concrete Piles; East River Tunnel. June 27, July 11, and Sept. 19, 1907.

Lowering the Grade of a Tunnel in Kansas City. Aug. 1, 1907.

Overbreakage and Falls in Tunnels; N. & W. Ry. June 18, 1908.

Underpinning a Tunnel on the Paris Underground Railway. Oct. 15, 1908.

the tunnel were destroyed by the military authorities. In 1872, they were reopened, and at the same time conduits were built to carry off the water. Later, water entered unexpectedly at the roof, but was taken care of by drains.

The difficulties of the construction and the inrushes of water which appeared from time to time had attracted the attention of the main-

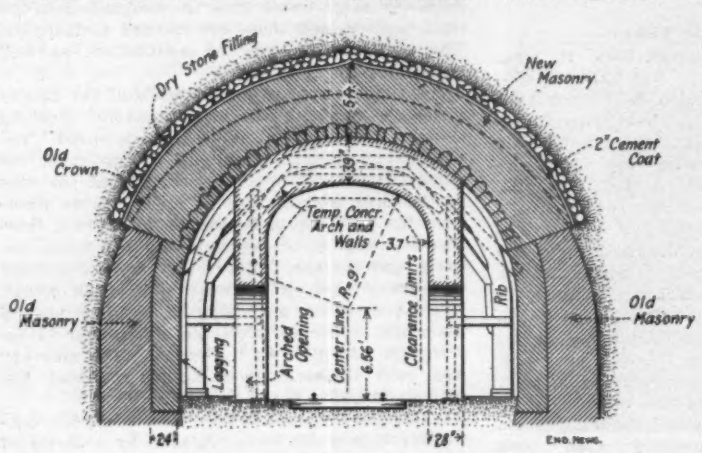


FIG. 3. HEAVY RECONSTRUCTION IN THE CHEZY TUNNEL (WITH TEMPORARY SINGLE-TRACK CONCRETE TUNNEL TO PROTECT TRAFFIC).

tenance department, and a careful study was made (commencing in 1894) of the construction records and the flow of the underground waters. From this study, six points were noted where irruptions of water might be expected and on which special watch should be kept.

On April 26, 1897, the roof collapsed for a length of about 33 ft., and traffic was blocked for 54 days. The accident occurred suddenly, and without warning. The tunnel men noticed the fall of some fragments of stone, and then a slight flow of clay through a crack near the center, and then the collapse occurred. There was time to stop trains, but not time enough to attempt to support the arch. This collapse occurred at a point where no indications of trouble had been found and where the masonry was perfectly dry. The character of the slip is shown in Fig. 2.

On climbing to the top of the pile of debris and examining the opening, it was apparent that the slip extended as far as the limestone, the lower level of which was known. It was hoped that the rock would arch over the opening and give time for placing timbering so that the slip would not extend to the surface. But the slip continued, and the fall of masses of earth and rock made it dangerous to investigate the breach. The most pressing need was to prevent the breach in the roof from extending. Centering was obtained as quickly as possible, and its erection was commenced as near the edge of the breach as possible.

But on the night of May 1, a body of water broke into the opening suddenly, washing away the clay debris in the tunnel and the timbering already erected. At the same time the limestone roof of the opening caved in, and the slip extended to the surface of the ground, about 120 ft. above the rails. This caused a panic and it took some time to reassemble the men and reorganize the work. It became evident that no temporary repairs could be made with a view to opening the line for traffic, but that a thorough investigation and reconstruction would be required.

The removal of the mud and debris and the erection of centering under the arch were carried on simultaneously. Each side of the fallen mass was attacked, heavily braced wooden shields being used, which were pushed forward by small successive movements. On account of the soft consistency of this mass, only small openings in the shields were permissible, to avoid the possibility of starting another flow. This added to the difficulty, as large blocks of stone were frequently encountered and had to be broken up. On June 13, the two excavations met.

The roof was rebuilt in the usual way, but with an unusual thickness in order to sustain the pressure of the moving masses in the slide. The thickness at the crown was 5 ft. The walls were rebuilt with a thickness of 5 ft. The depression in the ground had been filled with brush and timber in such a way as to brace the sides without greatly increasing the load. When the tunnel work was completed, the depression was filled and leveled.

After the first collapse, indications of crushing of the arch stones had been noticed in a neighboring part of the roof. But a careful examination, aided by the electric lighting system which had been installed within 48 hours after the accident, failed to show any alarming symptoms. Nevertheless, in the repeated examinations, other places were found where the masonry had commenced to move. In fact the same character of failure began to appear suddenly at a point apparently sound and perfectly dry about 330 ft. from the first slip. The arch was already on centering, but in a few hours the pressure was so strong as to crush the timbers, and orders were given to stop all trains until the threatened slip was under control.

The arch of the tunnel was rebuilt for a length of 2,000 ft., the thickness at the crown being from 32 ins. to 39 ins. or even 47 ins. in exceptional cases. At the crown, the curve of the extrados was replaced by two tangents, forming a triangular ridge with a height of 4 ins.; this facilitates the shedding of water. The side walls were rebuilt also for a considerable distance. It would have been difficult to place behind them a continuous backing of dry stone to form a filter or drain for the flowing water, but at points where a strong flow was encountered vertical drains of dry stone were built, about 3.28 ft. apart; between these drains the earth was allowed to pack directly against the wall.

The facing of the arch was made with granite, the stones being dressed to shape. The interior was of hard limestone or schist, the latter being used also for the side walls. The masonry was laid in cement. The extrados was covered with a quick-setting cement and a thick coating of tar to protect the cement from damage by the dry stone backing. Drainage water coming through this backing is provided for by weep holes in the walls.

Precautions were taken to prevent the imprisoning of the men by a new slip, and the roof was inspected frequently and closely. At one side of the tunnel a covered way was made by a line of ties set on end and inclined against the side wall, thus forming a means of escape should a slip block the tunnel. Traffic was operated on one track, under the protection of signals and the pilot system. As the clearance of the centers and timbering was very small, the shifting of the load on an open car might result in carrying away the centering and causing another fall of the roof. To prevent such an accident, a clearance gage, or loading gage, was placed at each end of the tunnel, and every freight train passed slowly under the gage before entering the tunnel. The gage revolved, so as to be turned out of the way of passenger trains.

The Chezy Tunnel.

This is a double-track tunnel near Chateau-Thierry, on the line from Paris to Strasbourg. It is 1,486 ft. long, and is driven through sand

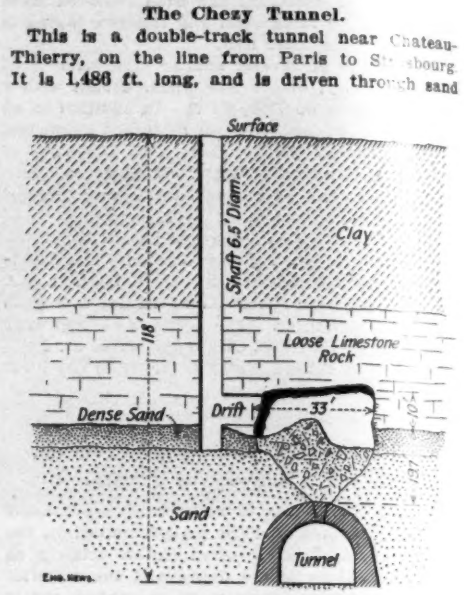


Fig. 4. Test Shaft and Drift to Locate the Slide Over the Chezy Tunnel.

and soft clay. The masonry lining was of an inferior limestone, and had suffered injury from frost, but had been repaired superficially. In 1898, it was seen that it would be necessary to reconstruct the arch, either for the inner ring only or for its entire thickness. It was observed that in demolishing one ring, cracks due to crushing were developed in the adjacent rings, due to the increased load thrown upon them. This showed that the masonry had nearly reached the limit of its strength.

At one point, while removing the old arch, a workman removed one of the voussoir stones without taking sufficient precautions. Two stones of the outer rings followed it, and a stream of fine dry sand poured through the opening. In less than a minute about 460 cu. yds. of sand had fallen, filling the tunnel to the crown. It was necessary to divert the heavy traffic to other routes, but fortunately the men in charge were able to climb up the sand and plug the opening, which had not enlarged. The debris was removed, and traffic resumed in 48 hours.

However, it was necessary to provide against any similar accident, which might have serious results if it occurred while a train was passing. Passengers had begun to complain also of the dropping of sand and debris on the roofs of the cars. There was no room to put a protecting

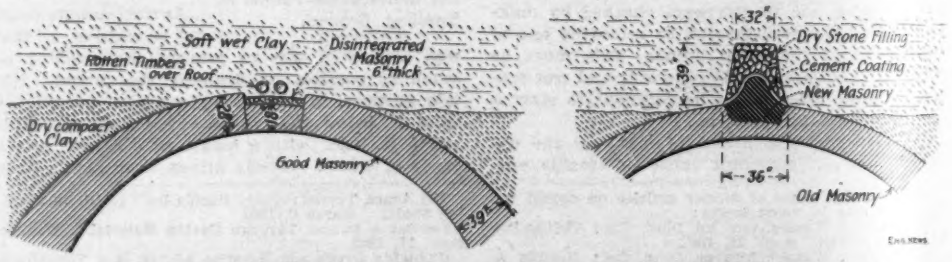


FIG. 5. RECONSTRUCTION OF THE CROWN OF THE MARNAY TUNNEL.

platform under the arch centering, as there was very little clearance. The contractor, Mr. Fougerolle, proposed to build a temporary single-track concrete tunnel inside the tunnel, the concrete arch enclosing the timbers of the centering. Arched openings were formed in the concrete side walls. This is shown in Fig. 3. It was required only for a length of about 50 ft. Trains passed in perfect safety while very small galleries were driven for the destruction and rebuilding of the permanent roof. Numerous vertical joints were purposely left in the concrete

work, but in spite of these the destruction of the temporary work was tedious and costly.

The old tunnel was only about 24.27 ft. wide and 18.70 ft. high. To enlarge it would have involved reconstruction for its entire length, but a slight improvement at the crown was made by increasing the radius of the intrados and prolonging the curve beyond the spring to meet curved side walls. This was done on account of the very small clearance of the old roof, which showed signs of having been struck by loads badly placed on the cars (or displaced by the vibration).

The tunnel work being completed, an investigation was made as to the effect of the irruption of sand. A shaft was sunk at one side of the tunnel, as shown in Fig. 4, and after some exploring a drift driven from this encountered the cave or chamber above the tunnel arch. The sand had formerly reached to and supported the limestone above. The chamber was refilled with sandy earth.

The Marnay Tunnel.

This tunnel, near Foulain, is 652 ft. long, and is driven through a bed of blue clay overlaid by a bed of oolitic limestone 50 to 60 ft. thick. In July, 1897, some fragments of the stone lining fell from the roof. This would not have been given much attention (being attributed to the effect of frost) but for a certain similarity to the collapse in the Montmedy tunnel. Drill holes showed that at the crown the masonry had not the normal thickness, and that the mortar had been weakened by the action of water.

Centering was hurriedly put in place, and in order to keep both tracks open (the traffic being heavy), ribs of very slight thickness were used, composed of old 74-lb. double-head rails 3.6 ft. apart. It was necessary, however, to lower the tracks 4 ins., the tunnel having been given a reduced height at this point, probably on account of the difficulties encountered during construction.

In rebuilding the arch it was found that not only was the thickness reduced at the crown, but that above it, at some places, were rotten timbers. For this reason, a small heading 32 × 39 ins. was driven above the crown, from openings in the roof. At each opening were four closely spaced ribs which supported the roof and served also to carry the working platforms. The key portion was rebuilt of the proper thickness, and in addition a rib of new masonry was formed as shown in Fig. 5. This tends to check movements of the ground and to shed water rapidly. The space above this (in the heading) was then filled with dry stone masonry driven tight with hammers.

The Pommeraie Tunnel.

This is on the same line as the previous tunnel, and while no indications of trouble were apparent, the drill holes showed unsatisfactory conditions. At one point, also, the mortar was disintegrating under the action of flowing water. It was desired to stop or divert the water before beginning work, and a test shaft was driven up from the crown of the arch through the clay to the overlying limestone. It was found that a thin stratum of rock lay on the clay but detached from the solid rock above, forming a basin for the water coming through the latter. In places the clay had been washed away, leaving this stratum suspended above the tunnel roof.

A horizontal gallery (with this stratum as its roof) was then driven towards the point where the water seemed to disappear, and this disclosed an opening 62 ft. long and 10 to 13 ft. high, as shown in Fig. 6. A drain was formed, vertical walls of masonry were built to support the loose stratum, and the void between this and the solid rock was packed with concrete to prevent accidents due to heavy falls of rock.

Test galleries were driven (as at the Marnay tunnel) to a total length of 360 ft. These permitted not only the repair of the key of the arch, but also the consolidation of the thin portions of the arch by means of successive ribs. The work and its inspection was very trying, especially when, through enginemen disregarding orders to shut off steam, a jet of smoke was discharged into the shaft, almost suffocating the men. No system of ventilation was practicable for these small and short headings.

The gallery disclosed another chamber similar to but larger than that above mentioned, having a length of 60 ft., a width of 52½ ft. and a height of 11 to 13 ft. The thin stratum of rock rested on the clay, which was settling under the action of water, and it is probable that a fall which would have broken in the tunnel roof

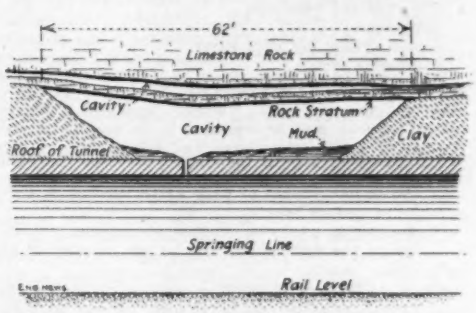


Fig. 6. Cavity Over the Pommeraie Tunnel, Due to the Washing Away of Clay by Flowing Water.

would have occurred in a short time. The arch was rebuilt and strengthened here by exterior ribs 28 ft. apart, on which were built walls reaching up to the surface of the rock. These walls were connected by arches, and by a boundary or retaining wall sloping outward, which held the clay in place.

At one point where the face stones had been spalled by frost, a facing of reinforced concrete had been applied, but the limited clearance prevented its being made thick enough to add to the strength of the lining. As it concealed the masonry, so that this could not be inspected, it was decided not to extend its use in a tunnel where moving clay might exert severe pressures.

All the work was executed without stopping traffic on either track. The ribs were of old rails, as noted above, with plank lagging. For the less important repairs, where ribs were not needed, a plank was placed on iron brackets hung from iron lugs driven into the joints of the masonry. The repairs at the sides of the arch were made from two-stage travelers mounted on section cars. To utilize the short periods between trains, when there was not time to put the travelers in position, platforms were hinged to the ribs, which could be folded back in a few seconds to clear the trains. For the upper part of the arch, the working platforms were suspended from the ribs.

During the work of removing some of the arch masonry, a miner was astonished to find behind the arch another arch lining. It seems that during the construction of the tunnel a mistake was made in giving the line on a curve, and a certain length already constructed was abandoned and left outside the new work on the corrected line.

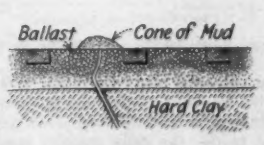


Fig. 7. Mud Wells in the Nanteuil Tunnel.

The Nanteuil Tunnel.

This tunnel, 3,680 ft. long, is in clay strata, and it was noticed that small piles of mud would form on the ballast. They were fed from holes or tubes opening at the tunnel floor, as shown in Fig. 7. The mud is formed in seams or fissures in the hard clay by the vibration and movement due to the weight of the trains, and under this movement and the pumping action of loose ties in the ballast it is worked to the surface. Some of these holes discharged as much as 0.35 cu. ft. per day, so that the ballast was soon choked. To remedy this trouble, a longitudinal drain was provided, in such a way that it could be cleaned easily.

The subgrade was trimmed and cleaned, and covered with a concrete floor (not an invert) 6 to 8 ins. thick, on which was laid a bed of broken stone. The result was satisfactory, except at points where the concrete had been laid in separate sections for each track. Here the mud worked up through the longitudinal joints, in spite of the special care that had been taken to effect a complete bond between the old and the new concrete. Such work was very expensive, as it necessitated single-track working for a considerable time, which is a costly necessity on a line having heavy traffic.

The arrangement of the central drain is shown in Fig. 8. This is designed to resist the lateral thrust of the soft material, which, with an open drain, might force the side walls inward. It is an oval masonry drain with frequent openings fitted with covers, through which tools can be inserted to clean out the mud and dirt which collects.

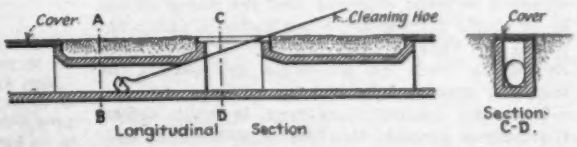


FIG. 8. DRAINAGE CONDUIT (IN SOFT GROUND) UNDER THE FLOOR OF THE NANTEUIL TUNNEL.

The Watertightness of Tunnels.

Few of the old tunnels are watertight. The cement covering of the arch is difficult to apply, and the drains and the dry-stone backing become clogged when the water carries sand or earth. The water is then under pressure, and eventually finds a way through the masonry. The damp stones decay sooner than those exposed to the outer air, and they are more readily attacked by frost. The water also disintegrates the mortar of the joints. Strong flows of water through sand form eventually subterranean voids or chambers in which dangerous slides may occur.

Numerous methods have been tried to make the masonry watertight. When there is much water over the arch, it may be drained by pipes laid in the lining or by vertical drains in the side walls. This prevents the formation of stalactites (which may be dangerous to enginemen or trainmen). In many cases, the water that threatens the safety of the tunnel may be removed by driving a parallel gallery, with lateral drains through the base of the side wall of the tunnel. But such works are difficult and costly, and do not always give the desired results. In some cases success is obtained by establishing longitudinal drains behind the side walls or at the branches. But the effect is not always permanent, the drains becoming clogged and the water seeking new channels outside of them. At the Nanteuil tunnel, the effect of a costly drainage gallery above the roof was only to increase the flow, and the tunnel received more water than before.

In certain cases, the amount of water may be reduced by surface drainage of the lands above the tunnel, or even by the establishment of masonry conduits. In the Rilly tunnel, which traverses a bed of chalk for nearly 2½ miles, there was one point which at times discharged great quantities of water. As this took place soon after heavy rains, the plan was adopted of confining the water to the surface, and this was successfully accomplished by comparatively inexpensive works.

One of the best methods of making the masonry watertight is the injection of cement or cement grout.* Joints are opened at certain distances, and the grout forced into one of these by compressed air. When the grout appears at another open joint, the operation is suspended, and commenced at another point. In this way the greater part of the water may be excluded, or (if the pressure is very heavy) the discharge

*Engineering News, Oct. 11, 1906, Nov. 25, 1909.

may be definitely concentrated at a small number of weep holes. The method has the advantage also of consolidating the masonry, and even the surrounding material, especially when this is dislocated rock. Another method consists in making hollow joints by means of rubber pipes, which are embedded in the mortar and then removed. But the conduits thus formed are soon obstructed, however clear the water may be.

To render the subgrade waterproof, the natural method is to establish conduits in the middle or at the sides. Where the earth exerts a thrust, the lateral collectors are dangerous, and even a central drain should be made in such a way as not to weaken the bracing of the footings. The manner in which this was done at the Nanteuil tunnel has been described above.

The Execution of Tunnel Repair Work.

The superficial repairs of the masonry can be made in ordinary double-track tunnels without converting the line to single track, as was done in the Marnay and Pommeraie tunnels. It is necessary to stop the work frequently to allow trains to pass, and the trains are run at reduced speed. But the cost of track changes is saved, and there is no danger of collisions. When the dimensions of the tunnel do not permit of setting the ribs, or when extensive work is to be done, it is necessary to close one track to traffic. There is some advantage in shifting the other track to the middle of the tunnel. Great care must be taken in the handling of the traffic.

For work of this kind, a special force is required, composed of men of large experience in tunnel works. Mr. Siegler considers that such a force cannot be maintained permanently by a railway company, and it is necessary then to employ contractors having a trained force of foremen, miners, timber men, etc. But it is difficult to award such work by general contracts, as the uncertain character of the work, the unknown conditions and difficulties, and the troubles due to keeping clear of traffic, deter contractors from bidding or cause them to bid excessive prices. He has found that the most satisfactory method is to make private agreements or contracts with reliable contractors, modifying the agreements according to circumstances. When there is a series of important works to be done, a special force may be organized and the work done under the direction of the railway company's engineers.

The difficulties and cost of such work and the troubles in operating traffic, are so great that in tunnel construction care should be taken not to adopt economies which may be regretted. In good and sound ground it is sufficient to employ a good quality of stone (unaffected by frost) for the masonry, and to exercise careful supervision over the construction. Carelessness and defective work are particularly difficult to avoid in tunnels, especially in the keying of the arches. In bad ground, the stone used should have a great strength to resist crushing, and the lining should be of ample thickness. When galleries and large drains are built to carry the flow of water, they should be made as accessible as possible, to facilitate maintenance and inspection.

When an important railway is built across treacherous ground, Mr. Siegler believes it better to build twin single-track tunnels. The first cost will not be greatly increased, as the difficulties increase rapidly as the section is enlarged, and there will be a saving in future maintenance. By stopping traffic in one tunnel, the work can be done without interference, while trains pass through the other at their regular speed. Indeed, the difficulties of strengthening an old double-track tunnel are so great, that Mr. Siegler suggests that in some cases it may even be advisable to adopt the extreme expedient of building a new single-track tunnel at a sufficient distance, and to close the large tunnel while the work is in progress.

AN IRRIGATION SYSTEM for the Boston Common is reported as being under construction. A considerable length of pipe will be laid beneath the Common, and sunken hydrants for hose connections will be placed at convenient intervals, thus affording facilities for watering the grass, shrubs and trees whenever necessary.

Cleaning Water Filters.*

By S. BENT RUSSELL,† M. Am. Soc. C. E.

The writer had occasion to visit a number of important [water filtration] plants last year and was especially interested in noting the results secured by washing appliances in practical operation.

The following matters come under the head of washing appliances:

Capacity of wash-water plant.
Storage for wash water.
Distribution of wash water.
Pressures and velocities.
Agitation.
Trough system for wash water.
Waste-pipe system.

The capacity of the wash-water plant and the size of the unit are, of course, mutually dependent. The required capacity may be expressed in its relation to other factors by a few simple formulas. The capacity may be measured in three ways, viz.:

Q_d = The amount of wash water required in a day of 24 hours.
Q_m = The maximum amount per minute.
Q_w = The amount required for one washing of one unit.

Let R = Rate of filtration = number of cu. ins. filtered per sq. in. of filter bed per minute;
and r = Rate of washing = number of cu. ins. of wash water required per sq. in. of filter bed per minute;
and c = Capacity of one filter unit in gallons per day of 24 hours.

Then
$$\frac{1,440}{c} Q_m = \frac{r}{R}. \qquad (1)$$

and
$$Q_m = \frac{r}{R} \times \frac{c}{1,440}. \qquad (2)$$

For a rate of 120,000,000 gals. per day R is about 3. For washing as done at Cincinnati r is 24 (see Table II).

Taking these values, $\frac{r}{R} = 8$ and $Q_m = .00555c$.

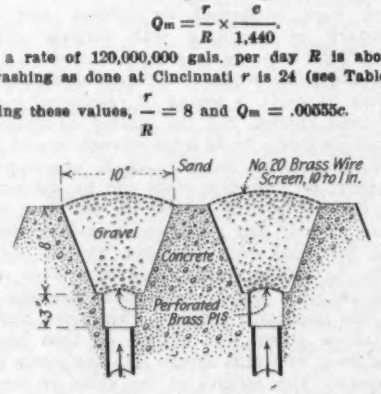


Fig. 1. Water Filter Strainer System at Cincinnati, Ohio.

For c = 1,000,000 gals. Q_m = 5,550. (3)
Let p = Number of gallons of wash water required to 100 gals. filtered, with worst water;
and t = Length in hours of filtering and washing cycle, with worst water.

$$Q_w = \frac{p\,c\,t}{2,400}. \qquad (4)$$

In a given case, if $p = 3$, $c = 1,000,000$ and $t = 12$, $Q =$ 15,000 gals., which is the amount required for one washing.

$$Q_d = \frac{n\,p\,c}{100} \qquad (5)$$

when n = the number of filter units. All values of Q are in gallons.

Now where a separate pumping plant for wash water is to be used, if there is no storage, the pumps must have a daily capacity equal to or greater than 1,440 Q_m. If we have storage equal to Q_w, the daily capacity must be not less than Q_d. Q_w is, of course, the minimum for storage capacity in that case.
Let $n = 10$, $p = 3$, $c = 1,000,000$; then $Q_d = 300,000$ gals. per day. If $Q_m = 5,550$, 1,440 $Q_m = 8,000,000$ gals. per day.

We may then have an 8,000,000-gal. pumping plant without storage or a 300,000-gal. plant with 15,000 gals. storage. In the above it is assumed that only one unit will be washed at one time. Q_d is independent of the size of the unit, but Q_m and Q_w will increase in proportion to the size of the unit. It is easily seen that, in the special case given, a 4,000,000-gal. pumping plant with not less than 7,500 gals. storage could be used for wash water, or other combinations could be made.

The value Q_m fixes the size of our piping and valves for wash water, while the number of valves and connections is determined by the number of filter units. The combined capacity of the wash-water pipes and connections is fixed by the total capacity of the filter plant and is independent of the size of the units. To put it another way, the combined capacity of our wash-water connections is nQ_m in gallons per minute. The question is, then, which is more economical for both first cost and operation, ten 20-in. valves or a number of 36-in. valves having equivalent total capacity. It is probable that up to 36 ins. the larger sizes will be more economical. It should be borne in mind that the first cost of valves and connections is a very important factor in mechanical filters.

The head required for actual washing is low and is, therefore, small compared with that for conveying and distributing the wash water. When we consider the great first cost of piping, valves, etc., and the small proportion of the work put into the wash water that is actually used, it appears that, in some aspects, the process of washing is a very inefficient one. This brings the thought that there may be here a field for profitable study leading to important savings. The point is that some cheaper way should be found of bringing the necessary amount of filtered water back under the filter bed with pressure sufficient for washing. It may be noted here that the volume of water used in a washing is usually from one to three times the volume of the sand in the bed.

At the new Cincinnati plant there are for wash water, two centrifugal electrically-operated pumps, capacity 25,000 gals. per min. each, and a storage reservoir on the hill 400 ft. distant of 190,000-gals. capacity. This storage is more than enough for two washings, while at the same time the pumping plant has twice the capacity required for washing.

The distribution of the wash water is a matter in which the size of the filter unit is an important factor. It is necessary that the wash water be made to rise uniformly through the entire bed. The difficulty of doing this evidently depends upon the ratios that the length and width of the sand bed bear to its depth. As the water will follow the line of lowest resistance it is necessary to make the resistance equal for all parts of the bed. Time will not permit our going into a detailed discussion of

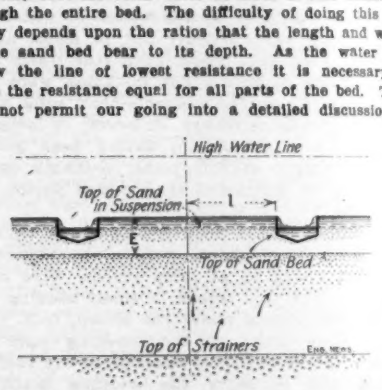


Fig. 2. Troughs for Waste Water from Washing Water Filters.

how this is done, but it may be noted that a new idea was tried in the Cincinnati plant. The wash water enters through perforated brass plates in the bottom of longitudinal concrete troughs which are filled with gravel. To guard against possible rising of the gravel the troughs are covered with brass wire netting above which is the sand bed. This netting is the novel feature (Fig. 1).

The pressure under such a strainer system as this is a matter of interest. The pressure must be sufficient to cause the sand to rise and be suspended by the current.
Let D = The specific gravity of a particle of sand,
and V = Volume of the voids in 100 volumes of sand;
S = Depth of sand bed in feet
H = Extra head in feet to raise sand.

$$H = \frac{(100-V)\,(D-1)S}{100} \qquad (6)$$

Let $V = 30$, $D = 2.6$, and $S = 2.5$.
Then $H = .70 \times 1.6 \times 2.5 = 2.8$ ft.

To see if the theory of formula (6) is correct, an experiment was made last year on a large filter under the direction of the writer. A glass gage was connected below the sand and the pressure was observed with an increasing upward flow of water. The difference in level of the water in the gage tube and that over the sand showed the lifting head. This head increased as the flow of water and without raising the sand until the critical head was reached, when the sand began to rise in spots. The measured head at this point substantially agreed with that shown by formula (6). Further increase in the flow did not materially increase the head.

It may be said by way of rough measurement that the extra head necessary to put the sand in suspension is, for ordinary sands, approximately equal to the depth of the sand.

As a filter cannot be properly washed without suspension of the sand, it is clear that the wash water must be supplied under sufficient pressure to provide this extra head at all points. This is an important factor in the design of the strainer system for beds of large area, but for lack of time, as stated above, we will only make this brief mention of it. Some differ-

*Being the major portion of a paper entitled "Notes on Certain Points in the Design of Large Filtration Plants," read before the Engineers' Club of St. Louis, April 7, 1909, and printed in Jour. Assoc. Eng. Soc., Vol. XLII., No. 6, June, 1909.

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ences in the strainer-system details of individual plants will be noted later, and in the bottom lines of Table I will be found further data in this connection.

It may be said that the head required for actual washing is approximately equal to the depth of the sand and, as noted before, we see that the work done in actual washing is small. It is known that the head lost in filtration through ordinary filter sand at 3 ins. per min. is about two-thirds of the depth of bed when the sand is clean. As the head of filtration may run as high as 8 to 12 ft. or more as the bed becomes clogged, it may be said that the head of washing is about one-third of the head for filtering, and if we are using 3% of wash water, the work of actual washing is probably less than 1% of the work of filtering. The work in HP. hours consumed for wash water in existing plants is far greater than this would indicate, however, for reasons already noted.

Agitation with air is used in many plants to assist washing. Air is forced under the bed and flows up through the sand and water. It is evident that the pressure must be not less than that due to a head of water equal to the depth of the sand. In practice about 3 lbs. per sq. in. in the supply pipes is used. From 2 to 3 cu. ft. of air per sq. ft. of filter per min. is furnished.

The uniform distribution of the air is, of course, a most important consideration. Now the resistance to flow of the strainer system must affect the distribution. In the table are given data indicating the comparative resistance of strainer systems to air.

It is probable that the net work of cleaning the sand is about the same with air agitation as when washing is done with water alone. About 3,000 cu. ft. of air for each agitation is required for a 1,000,000-gal. unit. In some plants the air is stored in tanks under high pressure. Less horse-power in engines and boilers is thus required, but the efficiency is also reduced.

Experience has not yet demonstrated which is more economical or advantageous in operation, agitation with air or a high rate of washing without air. In the matter of first cost, too, it is still an open question which system has the best of it. Where air is used, as in Harrisburg, however, without a separate pipe system, the first cost of the air plant is low, but, on the other hand, it is doubtful if a good distribution of air is thus obtained.

The design of the trough system above the sand bed to carry off the waste water while washing is an important matter. In the first place it is difficult to compute the true discharging capacity of a trough receiving water all along its length. In all plants seen in operation by the writer the troughs were more or less deficient in this respect. The actual capacity was less than the flow for which they were designed. On the other hand, too much excess capacity is undesirable. At each washing the volume of water in the trough system is wasted without useful effect and hence this volume is equivalent to clearance or lost motion.

As to elevation of troughs, experience indicates* that the sand, when in suspension, rises to a height approximately equal to the upward velocity of the wash water. If the troughs are set too low, the sand will be lost. If they are set too high, so much more water is required at each washing to obtain the same effect, as only the wash water that goes through the troughs is effective in carrying out impurities.

In good practice the troughs are spread not more than 6 to 7 ft. apart, as shown by maximum travel to trough (see table; for distance *l*, see Fig. 3.)

The waste-pipe system that takes the wash water with its load of impurities away to the point of disposal may be a matter of some moment. Its required capacity may be computed in the same way as the wash-water supply pipes. In most plants the waste pipes are of no great length, but where the filter plant is placed a long distance from a suitable water course the waste-pipe system may add a large item to the cost. In such a case, as the discharging capacity must be proportional to the size of the filter unit, the general design of the plant may be materially influenced. Moreover, it may be noted that in such a case agitation with air would have a distinct advantage over a high rate of washing without air.

We will now consider actual practice as to some of the matters above referred to. The writer had opportunity to see in actual operation the mechanical filter plants at Cincinnati, Little Falls, N. J.; New Milford, N. J.,* and Harrisburg, Pa. In all these plants rectangular gravity filter tanks of concrete are used. In each plant the writer saw the operations of washing carried out.

CINCINNATI, OHIO.—At Cincinnati the Ohio was in flood and the raw water very turbid. Only one of the primary settling basins was complete and in use. All the coagulating basins were in service. One and one-quarter grains lime and 2¼ grains sulphate of iron per gallon were being used, and most of the sediment was removed in the basins before reaching the filters.

With bad water, the filters were washed twice in 24 hours. Filtered water was used for washing. They were washed for one-half minute at less than half rate, then four minutes at a 2-ft. min. rate. Washing was stopped before the wash water was clear. Each washing took about 65,000 gals., and it was said that the consumption of wash water sometimes ran as low as 2%. As the writer remembers, the small troughs were overloaded while washing, but the collecting drain had excess capacity. The sand was completely in suspension at the 2-ft. rate. The washing was not, however, equally vigorous all over the bed. It was better at the end of the filter nearest to the wash-water supply main. This indicates that the friction in the distributing pipes under the filter is considerable. The filtered water was beautifully clear.

This is the largest mechanical filter plant in the world, and the first large filter plant for highly turbid water in the United States.

At the Cincinnati plant all gates for washing are operated by electric motors. They seemed to work well.

For regulating the charging of coagulants, a special alarm clock is used which strikes at regular intervals. The length of the periods can be quickly altered by changing the transmission gears.

The controlling device used for regulating flow is of a new type. An independent hydraulic motor is used to move the valve proper, giving a very close automatic regulation. The filters of this plant are entirely within the filter house, which makes inspection of them more attractive than in other plants.

LITTLE FALLS, N. J.—At Little Falls agitation with air is used. By a system of trapping, the air is made to pass through a smaller orifice than the wash water at each point in the strainer system. When the filter is ready for washing, the water is drawn down about 6 ins. below the trough weirs and the air turned on. The air is blown at a rate of 1,500 cu. ft. per min. for three minutes. The pressure at blower is 2½ to 3 lbs. per sq. in. The agitation lasts three minutes and appears to be very vigorous. The wash water is then turned on and the bed is washed at a rate of 9 ins. per min. upward flow. All valves for filters are operated by hydraulic cylinders. To run the filter plant, the superintendent and six men are on the day watch and two men only on night watch.

The Hackensack plant at the time observed was running at some disadvantage as the only settling basin was out of use and being cleaned. While speaking of this, it may be noted that this basin was at such a low elevation with respect to the river, which was considerably above low stage, that the drain pipe would not carry off the mud and water, which stood over knee deep in the middle of the reservoir. Cleaning was, of course, slow and expensive. About 2 ft. of pasty mud had accumulated in two and one-half years.

While the basin was out of service the raw water flowed on to the filters immediately after receiving the coagulant, making extra work for the filters. In the filters here the strainer system is of perforated plates at the bottom of square hopper-shaped chambers of concrete filled and covered with gravel, the purpose being to leave no dead space that might become foul. The air is brought by an independent set of perforated pipes above the gravel. The writer saw one filter washed and noted that the air agitation was not uniform throughout the bed. It was said, however, that this particular filter was the only one that gave trouble. In the plant as installed, the air for agitation was furnished by air compressors and tanks for storage under 150 lbs. per sq. in. pressure. A positive rotary blower is now used instead. All filter valves are operated by hydraulic cylinders. The plant was running at its full rated capacity at the time visited.

HARRISBURG, PA.—At Harrisburg the water is prepared for filtration by first adding one-half of the coagulant, then settling eight hours, then adding the rest of the coagulant and settling one hour. When the water is bad only three-eighths of the coagulant is added for the first treatment. It is thought that if this treatment were preceded by three hours' settlement without coagulant, better results would follow. The filters are washed when the head of filtration reaches 3½ to 5 ft. The head is never allowed to exceed 8½ ft. A unit is never run over 24 hours without washing, although it could be run 40 hours when water is good. When the water is cold the runs are shorter. At such times a filter is washed as often as five times in 24 hours.

The washing rate is about 9 ins. per min. and the troughs are overloaded, so that the best effect is not obtained. It is thought that better results could be had with a 12-in. rate and deeper troughs.

These filters have a very simple strainer system of perforated pipes. The air and water take the same course. The writer noted that the air is not well distributed at the beginning of agitation. The distribution gradually improves, however, and at the end the air is coming up all over the bed, although still stronger in spots. The agitation lasts three minutes, with about 1,000 cu. ft. per min., which is about 2.3 cu. ft. air per sq. ft. per min., and with 2 lbs. air pressure at blower. One filter was drawn down after washing so as to expose the sand. There were irregular areas of clean sand and areas covered with a dark deposit about ¼-in. thick. Washing without air has been tried without any apparent loss of efficiency, but it was not thought prudent to continue the practice. No storage is provided for wash water or for air. The waste water has to be disposed of by pumping when the river is high. All filter valves are operated by hydraulic cylinders. They give satisfactory service. The records show that these filters have given excellent bacteriological results.

COLUMBUS, OHIO.—The writer also visited the filter plant at Columbus which at the time was nearing completion. It is intended to soften and purify the water. Lime and soda ash solution will be used and if necessary sulphate of alumina will be added. The strainers are perforated plates in the bottom of concrete troughs, filled with gravel.* Air is supplied through separate pipes, as at the Hackensack plant. Storage is provided for both air and wash water. Air is stored at 60 lbs. pressure in overhead tanks in filter house. The expectation was to wash two to three minutes, then agitate, then wash two to three minutes again.

NEW ORLEANS, LA.—The new filter plant at New Orleans was under construction last year. The writer did not visit the plant, but was interested in learning its general features. The washing system is much like that of Cincinnati. No air agitation, but a high rate of upward flow, is used, and the gravel is held down by wire screens. The wash-water supply system has new features. The wash water is stored in long steel tanks extending overhead above the pipe gallery. These tanks are connected to an air receiver under pressure. There are no wash-water pumps. The wash water is drawn from the high-pressure pump mains.

OTHER PLANTS.—In the table are given dimensions and data of the mechanical filter plants above referred to. There have been included also similar notes of a mechanical filtration plant that was designed for St. Louis about eight years ago. This scheme was proposed by Mr. Edward Flad, then water commissioner. The writer assisted in making the design.

The plans are shown in some detail in the report of the water commissioner for the year ending April, 1902. Air agitation was included, with separate air distributing pipes

*Mr. Benzenberg, of the Cincinnati plant, stated that his experiments proved this to be true.

*Belonging to the Hackensack Water Co.

*The troughs are narrower and shallower than those shown in Fig. 1 and there is no wire netting above the gravel.

DETAILS OF VARIOUS FILTRATION PLANTS.

	New Orleans.	Columbus.	Cincinnati.	Hackensack Water Co.	Harrisburg.	Little Falls.	St. Louis (proposed) 1902.
Length of filter unit, ft.	53	27.67	50	46.67	26	24	80
Width of filter unit, ft.	27	46.67	82	25.8	16	15	44
Depth of sand, ft.	3	2.5	2.5	2.5	2.5	2.5	4
Height of weir above sand, ft. (E, Fig. 2)	2.5	1.0	2.5	1.0	1.33	1.0	1.17
Maximum travel to trough, ft. (l, Fig. 3)	2.44	3.2	3.5	3.2	3.4	3.5	3.5
Available positive head on strainers, ft.	10	....	5.5	....	....	7	....
Available negative head on strainers, ft.	8.5	....	2.5	....	....	3	....
Available total head for filtration, ft.	18.5	....	8	....	8.5	10	....
Depth of water on sand, ft.	6.5	4.2	3.0	4.17	....	4	4.5
Effective size of sand (mm.)	0.35	0.38	0.34	0.42—0.50	0.38	0.40	....
Area of strainer openings (%), water*	....	0.18	0.34	0.145	0.21	0.29	0.10
Area of strainer openings (%), air*	—	0.023	—	0.023	0.21	0.018	....
Loss of head in feet at strainer openings:							
†Filtering	....	....	0.05	....	0.15	....	....
†Washing	....	....	3.7	....	1.5	0.65	....
†Air	....	....	—	....	0.02	6.2	....
Date of installation, approximate	1909	1908	1908	1904	1905	1902	1902
Capacity of plant, million gallons per day	40	80	112	24	12	32	120
Capacity of 1 unit, million gallons per day	4	8	4	3	1	1	5
Number of units	10	10	28	8	12	32	24
Rate of filtration, million gallons per acre per day	125	120	110	120	80—120	125	63
Rate of washing, inches per minute flow	30	..	24	..	9	9	..
Agitation	—	Air	—	Air	Air	Air	Air
Air for agitation, direct pumping or stored	—	Stored	—	Direct	Direct	Direct	—
Wash water, direct pumping or stored	Stored	Stored	Stored	.....	Direct	Direct	.....
Time of settling, without coagulants	1 hr	—	48 hr.	—	—	—	12 hr.
Time of settling, with coagulants	7 hr.	12 hr.	5 hr.	12 hr.	8 hr.	1½ hr.	12 hr.

*The area of strainer openings is the net area or waterway and is given in per cent. of the filtering area.
†The loss of head given in the last three lines is computed with the coefficient of efflux for orifices in thin plates. For air the loss of pressure is measured in feet of water. All values are approximate only.

enclosed in the collecting pipes for water. The details present many novel features. Special effort was made to secure a good distribution of air and wash water on account of the great size of the filter beds. No gravel was to be used, as the writer remembers.

In addition to mechanical filter plants, the writer visited about a year ago the slow sand filtration plant at Pittsburg and the experimental plant in Jerome Park, New York. At the latter place the writer saw some test runs made with the Blaisdell patent filter washing machine.* This machine is electrically driven and travels over the sand bed, raking the surface and washing away the impurities. From 2 to 18 ins. in depth is washed. It seemed to do good work on a filter bed 15 ft. wide.

At Pittsburg the new plant was in operation. The water supplied to this plant has at times proved to be more difficult of filtration than was expected. At such times a rate of only 1,000,000 gals per acre per day is obtained. There are 43 units of one acre each. The writer took a special interest in the electrically-driven machinery which was on trial for scraping and washing and restoring the sand to the filters.

The Effect of Superheated Steam on Cast-Iron and Steel.†

Strength Tests of Cast-Iron Fittings After Use with Superheated Steam.

By IRA N. HOLLIS,‡ M. Am. Soc. M. E.

The failure of a number of large cast-iron fittings in use with superheated steam has rightly created a widespread suspicion of this material when exposed to high temperature. Yet on this subject there is very little information of a character to justify the wholesale substitution of steel castings for the ordinary heavy cast-iron fittings. The latter have been used with success for many years at all degrees of temperature below actual redness, and in many stations now in operation with moderate degrees of superheating (say 100° F.) cast-iron has never given the slightest trouble beyond the ordinary wear and tear.

The doubt as to the reliability of cast iron has seemed to spring up with its use in long pipe lines to steam turbines where the temperature has ranged from 550° to 600°. This would lead one to ask if the difficulty has not been in the design of the piping systems rather than in the character of the material. Has not the cast iron taken the brunt of a new service and has it not suffered in the estimation of the engineering public because the conditions of that service were not fully understood?

A vast amount of experiment and investigation would be required for the satisfactory reply to this question, and this brief paper is not intended as a reply, but rather to place before the society a record of some tests that may throw light on the subject. These tests were made for the Edison Illuminating Co., of Boston, for the purpose of determining the bursting strength under hydraulic pressure of some large fittings which were replaced with steel castings.

It may be well before giving the result of the tests to inquire what is actually known about cast iron subjected to high temperature; that is, known without the possibility of controversy:

(a) Fittings have developed cracks and small changes of shape after a few months of actual service.

(b) Fittings exposed separately to superheated steam at a temperature exceeding 500° F. have shown a permanent increase of some dimensions.

(c) The tensile tests of pieces cut from fittings that had failed in service indicate in some cases the possibility of permanent loss of strength.

The remainder of the evidence in the case may be classed as good guesswork based upon some preconceived theory as to the behavior of the constituent parts of cast iron in a rising temperature.

One of the curious and interesting qualities of cast iron is its permanent increase of dimensions under high temperature. This is paralleled by the permanent set of cast-iron test pieces when subject to very moderate tensile stresses. In both cases the cast iron apparently continues to grow at a decreasing rate, at least in some dimensions, when the high temperature or tensile stress is repeated. How long this growth would continue is not known. Its probable limit is the flow of the material under the ultimate breaking stress. Cast iron may not be peculiar in this respect and all materials may change permanently their dimensions under moderate stress, the change growing with each imposition of the same stress. There is no doubt of this where the yield point has been exceeded. It may also be that all materials change permanently under repeated application of high temperature.

The cause of the persistent expansion under high temperature is still very hazy, but two possible agencies have been mentioned in a number of discussions: (a) A chemical or physical change in the relation of the iron to the various foreign substances which fix it as cast iron. (b) A molecular change due to the fact that cast iron has no well defined elastic limit or modulus of elasticity.

Both causes may be in operation at the same time, but the theory of chemical change has far less standing than that relating to the stresses produced by unequal expansion. While there is a temperature at which carbon changes its relation to the iron, superheated steam is probably well below that point except under very unusual conditions.

That cast-iron loses strength when exposed to superheated steam at 600° is not conclusively proved. The most that can be said is that test specimens taken out of cast-iron fittings after one year or more of exposure to a temperature of 550° to 600° have shown a surprising irregularity of strength in the same casting. But there is nothing to prove that new cast-iron fittings have not a great lack of homogeneity. Irregularities exist in every casting owing to the inability of the metal to flow when cooling below a certain temperature. Furthermore, the strength of a test piece cast from a given heat can rarely be taken as that of any selected part of the fitting cast from the same heat. It is common experience to find variations of strain in castings as well as variations of texture. Were any large, irregular casting cut into small test pieces, the variations of strength would probably be found to be quite as great as that reported later on in this paper. The demonstration of the loss of strength after long service with superheated steam does not seem either complete or conclusive.

A very brief description of the essential features of the Edison station will help to make clear what follows. The new part of the station is arranged in a series of complete units each consisting of one vertical Curtis turbine and eight boilers set in pairs. The main steam line extends along the rear ends of the boilers just beneath the brick work, four 8-in. vertical steam mains connecting each pair of boilers with the main line. Three of the vertical mains discharge through gate valves into tees, and the fourth, at the end of the line, through a gate valve into a bend.

The first turbine units were provided throughout with cast-iron fittings, which were ultimately replaced with steel fittings. No expansion or slip joints are used. The main steam line (something over 103 ft. long) is anchored at the turbine end and is allowed to expand freely in a longitudinal or horizontal direction carrying the lower ends of the vertical mains with it. The steam pressure is 175 lbs., the superheating generally amounts to 150° F., although it is not constant. The actual temperature of the steam varies from 500° to 580°, so that the main line is changing in length from time to time, thus moving the lower ends of the vertical mains back and forth. A series of variable stresses are consequently introduced into all parts of the pipe system, probably affecting most seriously the tees. It is this aspect of the case, namely, the effect of varying stresses upon cast iron at high temperature, that must be studied before a sound verdict can be reached.

The castings in the South Boston station were first suspected of failure when nearly a year after the turbine plant had been put in operation one of the 8-in. by 6-in. by 6-in. tees near the boiler showed signs of deterioration, cracks appearing near the junction of the offset with the body of the tee and in the flanges. Another fitting of the same dimensions and location began to fail and was taken out after 14 months' service. Both these tees were cut up for testing and the results were so much alike that only the second is given here as that tee had been exposed the longest to the strain.

A chemical analysis gave the following: Carbon, 3.47; manganese, 0.10; phosphorus, 0.366; sulphur, 0.062; silicon, 1.41. The tensile strength of six pieces taken from different parts of the tee was found to be, 12,646, 14,295, 26,080, 27,270, 27,440, 28,280 lbs. per sq. in. There thus appears to have been considerable variation of strength in the tee unless the first two results are errors due to some faults in testing. Not considering them, the four other pieces do not appear to indicate any great falling off in service. They are as near together as would commonly be found in cast iron from the same heat. The material was supposed to be a first-rate quality of air-furnace gun iron which should have been good for 25,000 to 30,000 lbs. per sq. in., but no tests or analyses of the heat from which this tee was poured are on record.

Four test pieces cut from a larger tee, 14-in. by 12-in. by 8-in., which had had about the same service as that from which the foregoing test pieces were cut, gave a tensile strength of 23,130, 23,480, 23,875, 24,170 lbs. per sq. in. Here again there was absolutely no proof that the material had deteriorated.

Three test pieces were taken, for comparison, from a large manifold which had been seven years in service with saturated steam, and the tensile strength was found to be 16,413, 16,550, 17,000 lbs. per sq. in. The nature of the cast iron was not known positively, but it was bought as air-furnace gun iron.

It was fully recognized in the first of the foregoing tests that, while the material might not have suffered in service, nevertheless parts of the casting might have been weakened by the expansion stresses. For the purpose of testing this, two tees were removed from the line and broken by internal hydraulic pressure, thus affording a definite idea of the strength of the castings as a whole. A third casting, an elbow not previously in use, was added for comparison. The three fittings are shown in Fig. 1 in which the measured dimensions and the location of the fractures are given.

The material was the same as that used for all the fittings of the turbine unit, air-furnace gun iron, and the chemical constituents were probably about the same. The two tees had been exposed to superheated steam of 578° F. and less for 15 months, or longer, and when removed had given no indications of weakness. A careful examination disclosed no appreciable distortion except in the faces of the flanges which were no longer plane surfaces. There were several high spots that could not have existed when the flanges were faced off.

No. 1 was a 14-in. tee with an 8-in. offset. The openings were closed by heavy-cast-iron plates fitted to the flanges and bolted. The pressure was produced by a steam-driven outside-packed plunger pump, and was measured by means of a small conical safety valve, one-tenth of a square inch in area, and directly loaded by dead weight applied as the pressure increased. The indications of the small valve were constantly compared with a hydraulic gage previously tested and calibrated at the Crosby manufactory. The fitting broke as shown at an internal pressure of 1,650 lbs. per sq. in. The plates covering the openings did not reinforce the tee to any great extent as the bolts were smaller than the holes and the joints around the flanges were leaking appreciably when the fracture occurred.

No. 2 fitting was an 8-in. by 6-in. tee. It was broken in precisely the same manner as No. 1 and gave way at an internal pressure of 3,100 lbs. per sq. in.

No. 3 fitting was a 12-in. elbow. Its two openings were closed with cast-iron plates and it was burst in the same way as the others. The joints practically gave out at a pressure of 2,000 lbs. per sq. in. although the pressure was kept on for some minutes. For the second attempt to run the pressure up, the bolts were set up with a very heavy wrench, which undoubtedly put a bending moment on the flange. The fitting finally parted all around the root of the flange at a pressure of 1,500 lbs. per sq. in.

Four test pieces were cut from the larger tee and broken under tensile stress. Their dimensions were almost exactly ¾-in. in diameter by 6 ins. between fillets. Two of them were broken cold and gave a tensile strength of 22,150 lbs. per sq. in., and two were broken at a temperature of 590° at 20,050 lbs. per sq. in. The temperature of the latter was maintained by means of a cylinder-oil bath, the oil being placed in a large tube surrounding the test piece and kept hot by a gas flame.

No information could be obtained as to the original strength and chemical composition of the iron and it would be impossible to prove that it had changed either in strength or in composition. There is ground, however, for believing that it had changed, as the smaller tee mentioned gave as high as 28,000 lbs. tensile strength in one specimen.

A comparison of the larger tee with those tested and reported in the "Valve World" for November, 1907, throws an interesting light on the subject. The formula there published as derived from a very large number of tests of cast-iron and ferro-steel fittings may be taken as a basis for calculating what should have been the bursting pressure of the 14-in. tee. This formula is

$$B = \frac{T}{D} \times S,$$

where D = inside diameter of the tee.
T = thickness
S = tensile strength of the material multiplied by 60%.
B = bursting pressure in pounds per square inch.

Taking the tensile strength of the cast iron when hot at 20,000 lbs. per sq. in., the diameter of the tee at 14 ins. and the thickness at 1¼ ins., the value of B is 1,070 lbs. per sq. in., whereas the tee actually burst at 1,650 lbs. This did not seem to indicate weakness or deterioration.

It is interesting to inquire here what stress existed in the tee during its service. That due to the steam pressure was small when compared with the actual bursting pressure, but that due to expansion may have been serious in its effect. The first tee in the main steam line was located at 4 ft. 8⅝ ins. from the anchorage, the second 37 ft. 8⅝ ins., the third 70 ft. 8⅝ ins., and there was no expansion joint to ease off the pressure on the vertical mains. Taking the third tee for purposes of illustration, certain suppositions can safely be made:

(a) The lower flange of the vertical pipe moves in a horizontal plane as the main pipe expands.

(b) The upper end of the vertical pipe is practically fixed. The expansion of the main steam pipe thus puts an S-bend in the vertical pipe and introduces large bending moments into both ends of it and into the tee. The actual length of the pipe between its lowest flange

[*See Eng. News, March 12, 1908.]

†Three papers published in the December, 1909, "Journal" of the American Society of Mechanical Engineers.

‡Professor of Engineering, Harvard University, Cambridge, Mass.

and the upper end is 26 ft., but the length between the upper surface of the tee and the upper end of the pipe is about 28 ft.

The linear expansion of the main steam line is about 3 ins. when heated to 578° F. The effect of this is supposed to be halved by cutting the pipe short and springing the flanges into place when making the joints. There is thus an initial deflection in the vertical pipe. This is overcome as the pipe is heated and carried as much farther on the other side. The value of the deflection

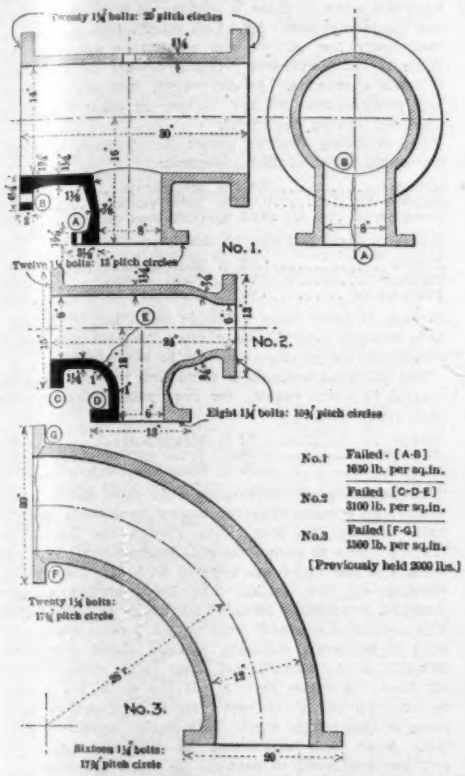
Twenty 1¼" bolts: 25" pitch circles
No. 1.
Twelve 1¼" bolts: 13" pitch circles
No. 2.
Eight 1¼" bolts: 10½" pitch circles
No. 3.
Twenty 1¼" bolts: 17½" pitch circle
Sixteen 1¼" bolts: 17½" pitch circle
No. 1 Failed - [A-B] 1630 lb. per sq.in.
No. 2 Failed [C-D-E] 3100 lb. per sq.in.
No. 3 Failed [F-G] 1300 lb. per sq.in.
[Previously held 2000 lbs.]

Fig. 1. Points of Failure of Three Cast-Iron Fittings Tested with Hydraulic Pressure.

(The two tees had been in use about one year with superheated steam 175 lbs. pressure; superheat, about 150°. The elbow had not been in use before the test).

in the lower end of the pipe is then taken at 1.5 ins. The maximum deflection of a beam fixed at one end and moved parallel to itself at the other end is

$$Y = \frac{WP}{12\,EI}$$

W = load in pounds or push of the horizontal pipe.
l = length in inches.
E = modulus of elasticity.
I = moment of inertia of the pipe.

The inside diameter of the pipe is 8 ins. and its thickness is 0.322-in., giving the value of $I = 72.5$. E is taken at 30,000,000.

The equation for the deflection is then

$$1.5 = \frac{312^2\,W}{12 \times 72.5 \times 30{,}000{,}000},$$

and W is found to be 1,288 lbs. Thus if the expansion of the pipe is exactly split by cutting the main line short, the push on the lower end of the vertical mains is 1,288 lbs. The point of contrary flexure in the S-bend of the pipe is about 179 ins. above the junction of the offset of the tee with its main body. The bending moment in the offset of the tee is therefore 1,288 x 179 inch-pounds and the stress set up is

$$S = \frac{Mc}{I} = \frac{1{,}288 \times 179 \times 5}{290} = 3{,}975 \text{ lbs.}$$

While this calculation is not entirely reliable on account of the uncertainty as to the elastic curve of the vertical pipe, nevertheless it is a fair indication of the stress to be expected in this tee when the temperature of the pipe reaches 578°. Furthermore, it is made under the supposition that the expansion of the pipe was lessened by an initial pull and that all the joints came exactly fair before setting up the bolts. It is easy to imagine how serious the stresses might have become under actual conditions of inaccurate fitting. The one element of splitting the expansion is very uncertain. The foregoing stress might easily have been doubled, resulting in pulling the tee quite out of shape and in setting up internal strains certain to weaken the material in places.

Under such conditions it was, and would generally be, wise to replace the cast-iron tees with cast steel which would yield more readily to expansion and which would be safer at much higher tensile stresses. The reason for the substitution ought not to be lost sight of in such a case, if cast iron is to be judged fairly. It is made because it is cheaper on the whole to replace the cast iron with steel rather than to put in expansion or slip joints. Perhaps the steel casting is also much easier to take care of than any form of expansion joint. The unreliability of cast iron in such a service has nothing to do with the case; it is merely that the design usually adopted for steam piping does not quite fit cast iron.

Effect of Superheated Steam on the Tensile Strength of Cast-Iron, Gun Iron and Steel.

By EDWARD F. MILLER,* M. Am. Soc. M. E.

The object of this paper is to describe some experiments made to determine the effect of superheated steam on cast iron, gun iron and steel. From each piece to be tested, two tension specimens were made, one to be subjected to the action of superheated steam, and one to be used in obtaining the original strength of the piece. All of the specimens were made with screwed ends in accordance with the specification prepared by the American Society for Testing Materials. The tension tests were made on a 100,000-lb. Olsen testing machine, the specimens being screwed into spherical holders attached to the heads of the testing machine, thus ensuring a straight tension pull without any bending.

The specimens to be subjected to superheat were placed on a wire grating suspended at the center of a 12-in. iron pipe about 3 ft. long, supported horizontally on brackets. The ends were closed by blank flanges. Steam was supplied by a small pipe, a flow at low velocity being maintained at all times. The under side of the pipe was heated by Bunsen gas burners. Thermometers, in wells reaching down to the grating on which the specimens were placed, gave the temperature of the steam, the pressure being read from a steam gage on the supply pipe.

For the tests plotted in Fig. 1, the average gage pressure in the superheating pipe was 93 lbs. and the average temperature 660° F. The gas flame was extinguished at 5 p. m. and lighted again at 7 a. m. The temperature reached 660° F. by 11 a. m. and by 5 p. m. would be as high as 700° or 720° F. Steam was kept in the superheater during the night. The total time these specimens were exposed to superheated steam was 260 hours, and the exposure to saturated steam was 460 hours. A chemical analysis of the iron tested is given in Table I.

TABLE I.—CHEMICAL ANALYSIS OF CAST-IRON SPECIMENS (FIG. 1).

	Phosphorus.	Total carbon.	Graphitic carbon.	Manganese.	Silicon.	Sulphur.
Cast Iron, Gibby Foundry	....	3.51	3.02	0.37	1.88	0.05
Gun Iron, Hunt Spiller	0.41	3.25	2.60	0.24	0.54	0.09
Cast Iron, Broadway Foundry.	....	3.34	2.84	0.38	2.26	0.09

For the tests plotted in Fig. 2 the average gage pressure was 82 lbs. and the average amount of superheat about 390° F. These specimens were subjected to superheated steam for 520 hours, and to saturated steam for 920 hours. A chemical analysis of three of the semi-steel specimens is given in Table II. This semi-steel was made by adding 200 lbs. of steel to 1,500 lbs. of cast iron. The analysis of the gun iron showed, total carbon, 3.37; graphite, 2.44; manganese, 0.34; sulphur, 0.11; silicon, 1.65.

TABLE II.—CHEMICAL ANALYSIS OF SEMI-STEEL SPECIMENS, FIG. 2.

Phosphorus.	Total Carbon.	Graphite.	Manganese.	Sulphur.	Silicon.
....	....	2.64	....	0.11	....
0.24	3.48	2.39	0.35	0.11	1.91
0.61	3.22	2.83	0.44	0.49	2.62

The composition of two of the rolled-steel pieces No. 26 and No. 27 was as follows:

	Phosphorus.	Total Carbon.	Manganese.	Sulphur.	Silicon.
No. 26..	0.85	....	0.73	0.026	0.026
No. 27..	0.116	....	0.90	0.057	0.031

In Fig. 1 and Fig. 2 the open circles (connected by solid line) represent the ultimate strengths per sq. in. of the original specimens while the full circles (connected by dotted line) on the same ordinate give the strengths per sq. in. of the comparison specimens which had been subjected to the action of superheated steam. By figuring the per cent. loss in strength in each specimen and then taking the average of those per cents. it appears that the cast iron from the Broadway Foundry (Fig. 1) lost 9.5%; that of the Gibby Foundry 2.4%. The cast-iron of Fig. 2 came from the Waltham Foundry; here there is apparently a gain in strength of 1.8%. Fig. 1 and Fig. 2 show that gun-iron loses strength; Fig. 1 showing a loss of about 3.5%, and Fig. 2 about 2.1%.

The tests on semi-steel show an average reduction of strength due to exposure to the steam, of about 0.4%, four out of six pieces showing quite a reduction. If piece No. 154 is not considered, the percentage reduction of strength would be much greater.

Four grades of steel were tested; two pieces from a bar of 65,000 to 70,000-lb. tensile strength, two from a bar of 75,000 to 80,000-lb. tensile strength, two each from three bars of about 90,000-lb. tensile strength, and two from a bar of over 100,000-lb. tensile strength. The 65,000 to 70,000-lb. steel showed a loss of 1.8% due to exposure to the steam, the 75,000 to 80,000-lb. steel a loss of 1.9%, the 90,000-lb. steel a loss of 1.5%, and the 100,000-lb. a loss of 24%.

While one is not justified in drawing many conclusions from the results of as few tests as are quoted here, still it is evident from Fig. 1 and Fig. 2 that the metals tested have suffered a loss in strength due to their exposure to the steam. A paper bearing on this subject, "Materials for the Control of Superheated Steam," by M. W. Kellogg, appeared in the 1907 "Transactions" of the American Society of Mechanical Engineers. In the "Valve World," March, 1908, are given the results of tests on cast iron taken from the body of a 14-in. valve which had been in use for four years on a main carrying steam at 200-lb. pressure and superheated to a temperature of 590° F. A number of test bars cut from the body of the valve showed a loss of strength of 41% when compared with the strength of the original metal as determined from coupons tested at the time the valve was made.

Gun-Iron Valves and Fittings Satisfactory for Superheated Steam.

By ARTHUR S. MANN,* M. Am. Soc. M. E.

There have been many failures of cast-iron valves and fittings in piping systems carrying steam of high pressure and high superheat. The ordinary extra-heavy, flanged, cast-iron fittings which are listed in many manufacturers' catalogues as suitable for 200-lb. pressure and which have to meet a close price competition, have successfully carried a pressure perhaps as high as 150 lbs. or more. No doubt the fittings and valves can support a steady pressure of 200 lbs. without bursting, but there have been many failures when carrying superheated steam of lower pressure.

These fittings are not too well suited for permanent work of even 150-lb. pressure, and many engineers in control of such matters in stations of a representative type prefer to design their own parts rather than to trust the usual run of commercial extra-heavy fittings. Probably on account of the advertised ability to support a high steady pressure, these extra-heavy fittings and valves have been used in a number of instances for superheated work. After a short time, six months or even less perhaps, cracks make their appearance; valves leak, seats become loose, castings grow in length and surface cracks become so large in size and in number

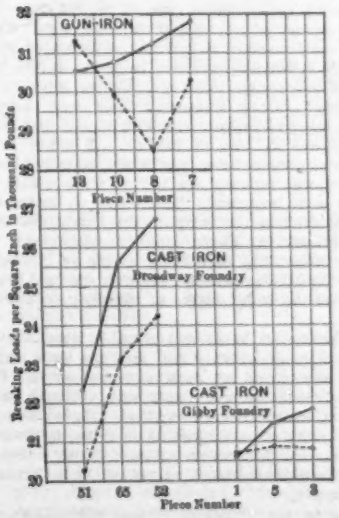

Fig. 2. Results of Tensile Tests of Gun-Iron and Cast-Iron Test-Pieces, Showing Effect of Subjection to the Action of Superheated Steam.

(Full lines connect ordinates for test pieces not treated with superheated steam. Dotted lines connect ordinates of test pieces exposed to superheated steam 200 hours; average gage pressure, 93 lbs.; average temperature, 660° F.)

that the casting is removed from the line. A few repetitions of this experience seem to justify the conclusion that cast iron is not fit material for high-temperature steam. The natural substitute is steel, which is used with fair, even complete, success in many cases.

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*Mechanical Engineer, General Electric Co., Schenectady, N. Y.

It is known that cast iron will grow with repeated heatings and coolings, often observed in the ordinary straight grate-bar. When the bar is first heated it expands, and cools as it contracts; but if the temperature has been high, the bar will have increased in length. With a second heating, a further increase takes place, followed by many others. As a consequence the long single, straight, flat grate warps and proves the wisdom of McClave's rule "Keep your long lines of metal away from the fire." This subject of growth has been treated very completely by Outerbridge in his excellent paper published in the "Journal" of the Franklin Institute for February, 1904. Mr. Outerbridge heated his samples to redness or above, temperatures greatly exceeding that to which a steam-pipe fitting is subjected.

A rough experiment on this line was tried by the writer with two samples, one of an ordinary cast iron and a second of a high-grade cast iron, which has proved itself capable of carrying superheated steam and of which a detailed analysis is given in the following pages of this paper. The two samples were each 6 ins. long and 1 in. in diameter. They were placed in a banked fire over night, reaching a dull red heat, and were allowed to cool in the air. A slight growth as measured by micrometer was found in each piece. This treatment was followed for two or three nights and the growths were measured. There was an increase in the length of each of the samples, the high-grade iron having increased in length slightly more than did the ordinary iron. The experiment so far as it went tended to show that the growth of cast iron does not necessarily unfit it for the usual degree of superheat in power-house work.

Many grades of brass will crumble when heated in a forge to a barely visible red, and are quite unfitted to support any stress at such a temperature. But this characteristic in no way unfits very ordinary cast brass for saturated-steam work, and one should not hesitate to use a valve of cast brass up to 3 ins. in diameter for 150-lb. saturated-steam pressure. Three inches is not usually exceeded because valves of large brass bodies are expensive.

Articles have appeared in various publications showing the disability of cast iron as shown by tensile tests made before and after the use of fittings of ordinary iron. Cases of bronze seats dropping from valves were cited and it was not difficult to prove that something better than ordinary cast iron was needed for steam of 180-lb. pressure and 250° superheat. These failures came from two causes. In the first place the iron itself was not of sufficiently good quality; and, secondly, the parts were not thick enough. The static stress probably did not exceed 1,000 lbs. in the body; but static stress is not the important load which fittings have to support.

Stresses from expansion and contraction within and without the casting and stresses from pulling up joints no doubt greatly exceed the static load even in pipe very carefully erected. The troubles are aggravated by the action of the steam itself, but it is yet to be proved that the steam or its high temperature will of itself start cracks in a properly designed fitting.

The ordinary commercial extra-heavy flanged tee, of 8-in. inside diameter, has a body ⅞-in. and flanges 1⅛ ins. thick. It is made of common iron, having a tensile strength of about 18,000 lbs. Such a fitting will fail with superheated steam at 175-lb. pressure and 200° superheat. Within a year the inner surfaces will have a network of cracks, some of which will increase in depth till they extend through the body. The flanges will crack outward from the bolt holes and the fitting will become not only leaky but dangerous as well. The writer has observed just such castings, an analysis of some of them being given later in this paper. Similar effects have been experienced by a great many steam users. The fittings are inherently weak to begin with, so that the failures do not prove that a heavier fitting of better iron is unsuited for superheated steam work.

Within the experience of the writer, steel fittings have failed with superheated steam. Out of 25 steel gate valves, 6, 8 and 10 ins. in diameter, not more than four were fairly tight after one year's service, the bodies themselves yielding enough to leak badly. Some defects in the castings developed, allowing steam to pass straight through the walls. Some of these defects were such that the fittings and valves could not be repaired. In some cases, seats were scraped in once or twice and holes were plugged up or patched, but the material would not have been satisfactory without this working over. Yet all these castings were heavy, materially thicker than the commercially extra-heavy cast-iron product, and had passed a rigid inspection.

Fig. 1 shows a 10-in. steel fitting; the irregular line at A showing a defect developed after use. The line does not pass clear through the casting, and no doubt the piece was amply strong to resist rupture even after the fault developed. Some of these fissures went 3 ins. back and 5 ins. broad. Such a large opening in a shell is objectionable for there are blow-holes enough adjacent to it to pass steam in large quantities. Some fittings of this kind were removed from the line entirely, while others were plugged or patched.

No doubt a thoroughly sound steel casting is able to withstand highly superheated steam. There are several connected to the system under discussion. So far as it has been possible to observe, superheated steam does not of itself initiate defects and it is not supposed that the sound metal undergoes a change, either chemically or structurally. But if there is an initial defect, superheated steam is active in bringing out the objectionable features of that defect. It may well be that the material within the body, and not a part of the actual metal, suffers through change of some sort. This material does not add to the strength of a casting but it may serve to stop up holes if allowed to lie undisturbed.

It would appear that some material better than the ordinary steel casting was desirable for high temperature work. Such a material is found in gun iron. Gun iron is nothing more than a high-grade cast iron, which any first-class iron foundry can produce. In the days of the smooth bore cannon, a few foundries discovered that it was possible to produce an iron having a tensile strength of 30,000 lbs. or more. The government specified it for its guns and it was called gun iron. Probably a tensile strength of 30,000 lbs. is not needed in steam fittings, but iron of that quality is well adapted for 175-lb. steam with 300° superheat.

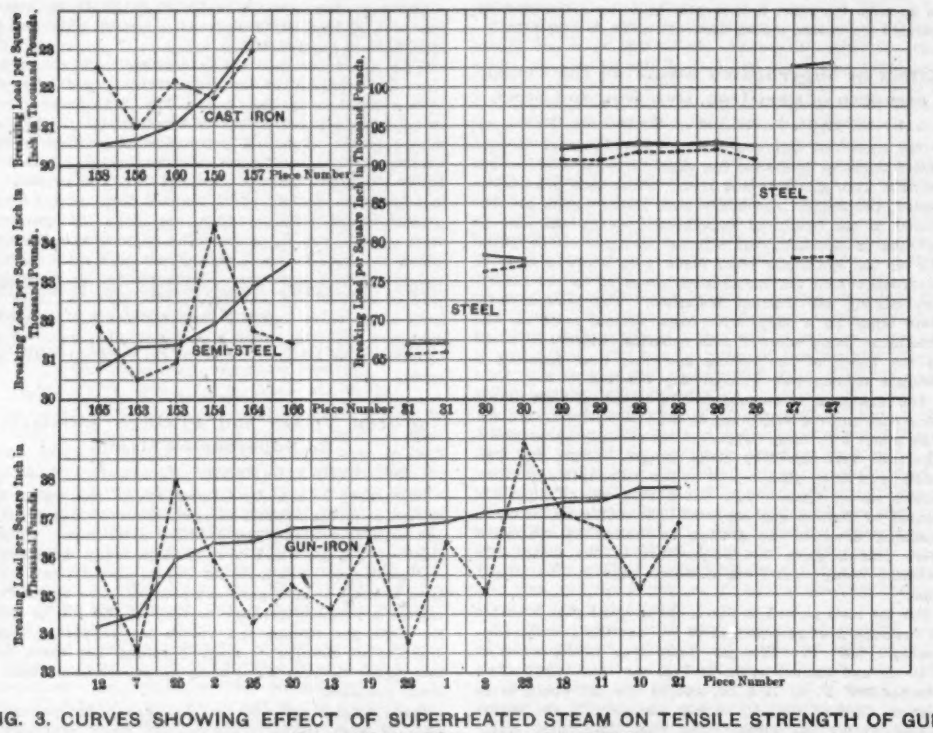
Breaking Load per Square Inch in Thousand Pounds.
CAST IRON
158 156 160 159 157 Piece Number
STEEL
Breaking Load per Square Inch in Thousand Pounds.
SEMI-STEEL
165 163 153 154 164 166 Piece Number
STEEL
31 31 30 30 29 29 28 28 26 26 27 27
Breaking Load per Square Inch in Thousand Pounds.
GUN-IRON
12 7 25 2 26 20 13 19 22 1 8 23 18 11 10 21 Piece Number

FIG. 3. CURVES SHOWING EFFECT OF SUPERHEATED STEAM ON TENSILE STRENGTH OF GUN-IRON, SEMI-STEEL AND CAST-IRON.

(Full lines connect ordinates for original test pieces. Dotted lines connect ordinates for test pieces exposed to superheated steam 520 hours; average gage pressure, 82 lbs.; average superheat, about 390° F.)

From such observations as have been thus far possible, it appears that certain elements in the iron are liable to cause trouble when present in excess, and perhaps the worst of these is silicon. It is at present going too far to say that every high silicon iron will fail and that every low silicon iron will prove successful, but there is much evidence pointing toward the correctness of such a surmise. In any event, iron of low silicon, low phosphorous and low carbon—in other words, gun iron—has proved successful.

The following analysis shows the character of a casting which failed at 250° superheat:

Silicon	2.40 %	Manganese	0.52%
Sulphur	0.067%	Total carbon	3.19%
Phosphorus	0.94 %	Combined carbon	0.23%

A failure developed also in this iron:

Silicon	1.98 %	Manganese	0.42%
Sulphur	0.068%	Total carbon	3.31%
Phosphorus	0.65 %	Combined carbon	0.24%

In each of these cases a sample was taken by drilling a hole straight into the body after the part had been in service a year or more and was in bad condition.

The following analysis is of an iron that has been successful in every respect for four years under 300° superheat:

Silicon	1.72 %	Manganese	0.48%
Sulphur	0.085%	Total carbon	2.45%
Phosphorus	0.89 %	Combined carbon	0.17%

The latter sample is from an 8-in. valve and it is tight to-day, no repairs whatever having been made upon the valve during the four years though the bonnet was taken off once to permit internal examination. The outer surface of the valve was covered with 85% magnesia insulation 4½ ins. thick. The inner surface appeared sound; a microscope revealed no cracks or other defects. The unfinished surfaces were struck several sharp blows with a ball-peen hammer, a hand chisel was driven straight at the surface and some thick chips were cut off from the rough portion. If the metal had suffered to such an extent as cast iron is supposed to suffer, some of the defects would have made themselves manifest. After these treatments, the valve was reassembled and has continued to perform its work properly.

Foundrymen are not afraid to attempt to produce this iron. No difficulty whatever was encountered in securing bids for valves made of the following mixture:

Silicon	1.40 to 1.60%
Phosphorus	0.20 to 0.40%
Sulphur	0.06 to 0.09%
Manganese	0.45 to 0.75%
Total carbon	3.00 to 3.25%

It will be noted that the percentages of silicon and phosphorus are low. There is of course a decided advantage in depending upon chemical analysis for determining the suitability of fittings. A hole can be drilled at any time in the actual fitting and a few grams of sample secured. Very few of us are willing to destroy a fitting to obtain a test bar, and test coupons cast in the foundry may or may not represent the actual piece.

Superheated steam was in commercial use in Europe before the practice had gained its present hold here. England and Germany were using superheated steam 20 or more years ago. The writer has not discussed this subject with engineers from abroad, but wishes to quote briefly those who have. E. D. Dickenson, of Schenectady, on a recent trip abroad asked a great many manufacturers whether they used steel for their superheated work and received a negative reply in each instance. When the manufacturer was questioned in regard to his iron mixture, he shrugged his shoulders and replied that he made his iron fit his needs, be it gas-engine cylinder or steam pipe. John Primrose, in "Power and the Engineer," for June 8, 1900, states that he discussed the matter with English and German engineers. In one instance a well-known German engineer, who had used superheat for 25 years, was surprised that he had not learned of the effect of superheated steam upon cast

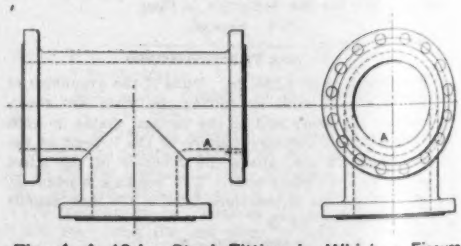

Fig. 4. A 10-in. Steel Fitting in Which a Fissure Developed as Shown at A after Use With Superheated Steam.

iron. The engineer promised to investigate the matter in Germany, but he could find nothing to bear out the contention and could find no one who believed that such a thing was possible.

It is not the author's intention to state that steel of good quality will not do for superheated work. Some manufacturers are putting out fittings of open-hearth steel which are doubtless good; but any foundry can make gun iron if it will, and delay and uncertainty will be decreased by its use.

On the Depth of Laying Water Pipe.*

Three hundred and twenty circulars (appendix) have been sent out, to which ninety replies have been received. The information required by the circular was of two classes, the first comprehending general data in regard to local conditions and practice in laying water pipe, and the second covering the results of particular experiences in freezing.

Concisely, it may be stated that the result of the investigation made by your committee is largely negative in character: that is to say, it appears that freezing has not occurred at the depths generally adopted for laying water pipe. Whether these depths are excessive, however, cannot be predicated from the information at hand, because where freezing has occurred there has always been an obvious explanation, usually little or no velocity, and an analysis of these explanations and of the local conditions pertaining does not finally justify any general deduction as to necessary depths.

Considering the results of our investigation in greater detail, reference may be made to the appended tables [only one reprinted—Ed.] which summarize the replies received to the questions of the circular. While these replies do not provide the information necessary for conclusions of much practical value, it is believed that there is sufficient information contained therein to make their publication worth while. There is little doubt that if a more general response to the circular had been obtained something of real value might have been worked out and it may be that the presentation of the data now collected will provide a basis for future work and stimulate further study of the problem.

From the tabulations it is apparent, as already stated, that in general the depths now used are sufficient to prevent freezing, but it is less evident whether or not these depths could safely be reduced. Either it must be concluded that present standards express the results of a gradually developed experience and that the present depths are the least which would be safe, or else there is a possibility of lessening these depths without danger. This conclusion is indicated from the fact that with practical unanimity all replies state that the present depths are sufficient, and a considerable number suggest that lesser depths might safely be used. Whenever freezing has occurred it has been largely at night or where there was practically no current, and it is believed that where there is a velocity, say, in excess of one-quarter of a foot per second, and particularly in the case of ground water supplies, depths somewhat less than those now used would generally be safe. In main feeders, and in those portions of the distribution system where there will be an assured circulation, the question of minimum depths should be given careful consideration. It is not in the mains but in the services that most of the trouble from freezing occurs, and in the services such trouble usually results from skimping by plumbers or contractors, resulting in the actual laying of the services at depths considerably less than the mains. There is a strong feeling apparent that services should be laid by the municipalities.

Twenty-eight of the places replying report the tapping of service connections on the top of the main, 39 on the side, 12 on the quarter, and 7 in various ways. Freezing of services generally starts at the house and backs out into the main, and it is believed that if services were tapped on the side of the main and then dropped to the depth required to meet local conditions, the lessening of the depth at which the main is laid to that justified by the velocity of the water in the main will not result in increased freezing of services.

In determining the depth of pipe, the character of the soil and the surface of the ground are factors of some importance. In but very few places, however, from which replies were received is the nature of the soil taken into account in deciding as to the necessary depth at which the pipes should be laid. In 10% of the replies it appears that some attention is paid to the character of the street surface, although apparently there is no prevailing rule. Some consider that a pavement is equal to one foot of cover; others that pipe should be laid deeper in a paved street. An average of the replies received indicates that freezing extends 1 ft. deeper in streets than in fields; also that in streets frost will reach 1 ft. 5 ins. deeper in gravel than in clay, with sand half way between. In fields it would appear that frost will extend 1 ft. farther in gravel than in clay, with sand again intermediate in effect. It is obvious that the character of the soil is a factor of such relative importance as to demand consideration in determining the economical depth.

Fifty-three places report actual experience in the freezing of pipes. All of these cases were in distribution systems and none in the leading mains. Fifty per cent. were on dead ends and all were in pipes where there was little or no velocity. All but three of the cases of freezing were in pipes smaller than 10 ins. in diameter, only seven in pipes as large as 8 ins. in diameter; in all cases the ground was frozen below the axis of the pipe, and the ground water level was also below the pipe. In 80% of the cases the ground was bare of snow at the time of freezing. All stoppages were total. Thirty-five places report the character of the soil in which the pipes were laid; of these, 40% were in clay, 48.6% in gravel, 5.7% in sand, and 5.7% in rock.

Table 3 [the only one reprinted] shows the latitude, average yearly and minimum temperatures (based on the United States Government Reports) of the places from which replies were received and also the depths at which the pipe was laid in these places. Obviously the temperature depends on other factors than latitude, and, believing that the mean temperature of the coldest month would provide a more satisfactory basis of comparison, a diagram [which we have reproduced] with this temperature as the scale of the horizontal coordinate, and the depth, as reported, as the vertical coordinate, has been prepared. On this diagram the different places, from which replies were received, have been plotted. There is much variation in the relation of depth to temperature of coldest month, as indicated by the practice in different cities and towns. Presumably this is explainable in most cases by peculiar local conditions; in others, perhaps, by an illogical adaptation of depth to the requirements.

On this diagram a line has been drawn which expresses the relation of depth to mean temperature of coldest month as indicated by an average of the replies received. It will serve to emphasize the variation in depth in cities and towns with the same mean temperature of coldest month, which in the extreme is illustrated by Mauch Chunk, Pa., and Cleveland, Ohio, the former satisfactorily operating pipes at a depth to axis of 3 ft. 6 ins., and the latter believing 6 ft. 6 ins. to be necessary. Obviously, local conditions other than temperature, and including depth of snow covering, must furnish, in great part, the explanation.

There is quite a marked grouping according to the depth used for pipe of cities and towns located geographically close to one another. The lesser depths employed in those places which appear below the average line are not explained by the use of ground water supplies, as there are as many ground water supplies above the average line as below. Those using shallow depths report practically no trouble, and the question remains whether this immunity results from peculiar local conditions or whether the general practice is unduly conservative. As already stated, it would seem that where there is any velocity of current, depths somewhat less than those indicated by this average line will generally prove sufficient to prevent freezing.

While all cases of freezing reported are stated to have resulted in total stoppage of the pipes, there are records of ice formation in concentric rings in pipes as large as 24 ins. in diameter, the occurrences not being evidenced by stoppage of the large main, but only by loss of head through increased friction, or, in some cases, by stoppage of gates or smaller pipe connections by the ice loosening and breaking up in a thaw and forming an ice jam at some point of obstruction. Such formation of ice in a layer adjoining the metal of the pipe has occurred in instances of extreme low temperature in the eastern Canadian Provinces in conduits where there was a considerable velocity. Obviously, as the ring of ice forms, the velocity of the water increases and a total stoppage does not result. In other cases of freezing, particularly in smaller pipes, the ice formation is not solid nor does it start from the outside, but is rather in the form of "slush" uniformly distributed throughout the cross-section of the pipe. This has been noted in a 4-in. pipe, in which there was considerable velocity, laid at a depth of 6 ft. in a salt marsh in New Brunswick.

There is a belief or tradition in the minds of many plumbers and water-works superintendents that most stoppages by ice formation occur in a thaw which follows a period of severe cold weather, and the reason generally advanced for this alleged phenomenon is that the

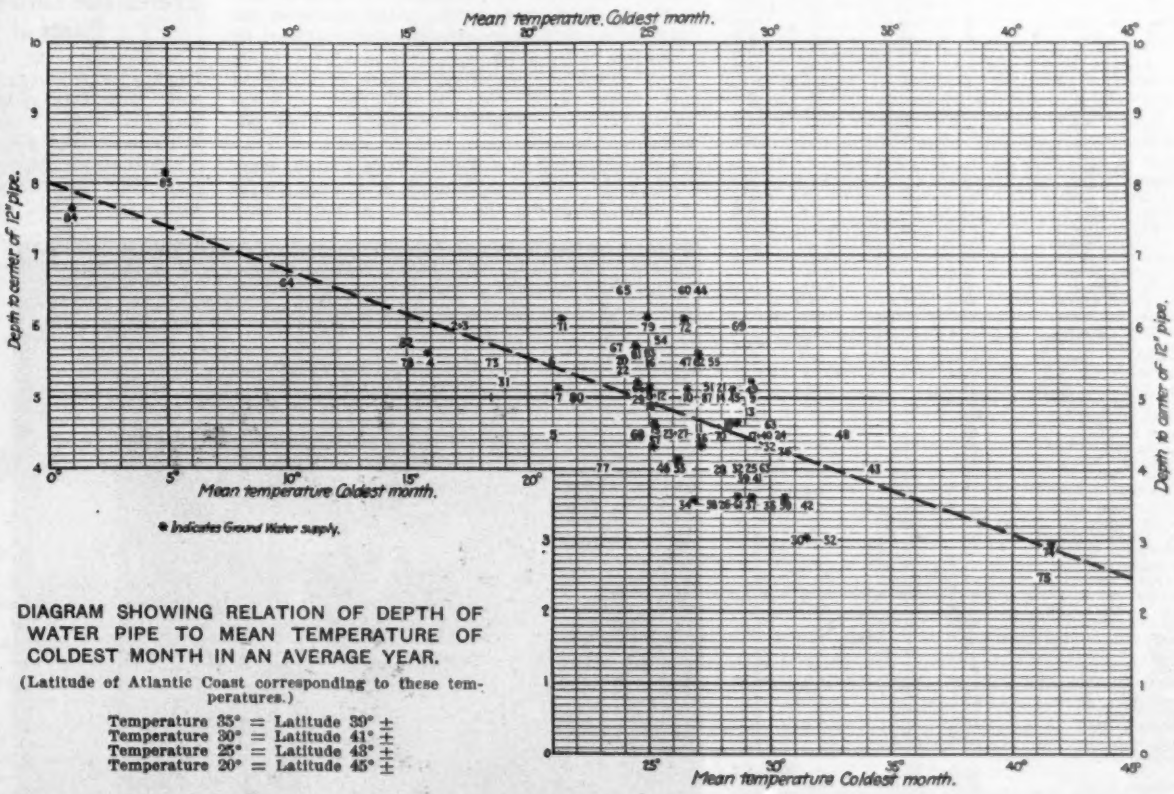
Mean temperature Coldest month.
Depth to center of 12" pipe.
Mean temperature Coldest month.
* Indicates Ground Water supply.

DIAGRAM SHOWING RELATION OF DEPTH OF WATER PIPE TO MEAN TEMPERATURE OF COLDEST MONTH IN AN AVERAGE YEAR.

(Latitude of Atlantic Coast corresponding to these temperatures.)

Temperature 35° = Latitude 39° ±
Temperature 30° = Latitude 41° ±
Temperature 25° = Latitude 43° ±
Temperature 20° = Latitude 45° ±

*Abstract of a Report of a Committee of the New England Water Works Association, submitted Dec. 8, 1909; F. A. Barbour, Chairman; W. C. Hawley, W. C. Head, Emil Kuichling, R. S. Lea, Dabney H. Maury, R. Winthrop Pratt. The full paper, with large tables on folding insert sheets and a map, none of which are here reproduced, will be printed in the Journal of the Association.

TABLE OF CITIES AND TOWNS, ARRANGED IN ORDER OF THEIR LATITUDE, GIVING AVERAGE YEARLY AND MINIMUM TEMPERATURE, BASED UPON UNITED STATES GOVERNMENT REPORTS, AND DEPTH TO CENTER OF PIPE IN DISTRIBUTION SYSTEM.

	Latitude, approx.	Temperature. Av. yearly.	Temperature. Minimum, extreme.	Depth to center of pipe, ft.
Edmonton, Alberta	53.5	37.0±	−30±	*8.0
Regina, Saskatchewan	50.5	36.0±	−50±	*7.5
Winnepeg, Man.	50.0	36.0±	−53.5±	7–8
Everett, Wash.	48.0	52.0±	24±	2.83
Hoquiam, Wash.	47.0	51.0±	18±	2.5
Ashland, Wis.	46.5	40.0±	−32±	*6.0
Charlottetown, P. E. I.	46.2	42.0±	....	*5.0
Pembroke, Ont.	45.8	....	....	5.75
Montreal, P. Q.	45.5	42.0±	....	†6.0
Bangor, Me.	44.8	43.6±	−21±	6.0
Brewer, Me.	44.8	43.6±	−21±	6.0
Rumford, Me.	44.5	43.1	−17	*5.0
Belfast, Me.	44.4	43.6±	−21±	6.0
Kingston, Ont.	44.2	44.6±	−19±	5.0
Auburn, Me.	44.1	45.0±	−11±	4–5
Ludington, Mich.	44.0	46.0±	−10	*4.0
Yarmouth, N. S.	43.6	44.0±	....	4.0
Rochester, N. Y.	43.2	48.6	−3	4.75–8.0
Mason City, Ia.	43.2	47.4	−13	6.0
Brantford, Ont.	43.1	50.0±	....	*5.5
St. Catherines, Ont.	43.1	....	−18±	*5.0
Dover, N. H.	43.1	46.0±	−10±	4.5
Manchester, N. H.	43.0	46.0±	−10±	4.5–5.5
Milwaukee, Wis.	43.0	47.9	−1	*6.0
Grand Rapids, Mich.	43.0	48.7	−6	5.75
London, Ont.	43.0	46.3±	−20±	*5.0
Canandaigua, N. Y.	42.9	49.0±	−3±	*4.5
Waterford, N. Y.	42.8	49.0±	−10±	5–5.5
Nashua, N. H.	42.8	47.7	−8	5.0
Billerica, Mass.	42.6	50.0±	−3±	*4.5
Fitchburg, Mass.	42.6	47.9	−5	*4–5
Lowell, Mass.	42.6	49.6	−3±	†5.0
Lowell (locks and canals), Mass.	42.6	....	....	5.5
Reading, Mass.	42.6	50.0±	−3±	5.0
Ann Arbor, Mich.	42.5	49.1	−4	5.0
Boston, Mass.	42.4	50.0	−1	5.0
Brookline, Mass.	42.3	50.0±	−1±	4.5–5
Cambridge, Mass.	42.3	50.0±	−1±	*4.0
Hyde Park, Mass.	42.2	50.0±	−1±	*4.5
Worcester, Mass.	42.2	49.0	−4	4.5
Sharon, Mass.	42.1	48.0±	−5±	5.0
Springfield, Mass.	42.1	51.6	−5±	5.5
Stoughton, Mass.	42.1	49.0±	−5±	†3.5–5.5
Westfield, Mass.	42.1	52.0±	−5±	5.5
Elgin, Ill.	42.0	48.5±	−1±	*6.0
Rockville, Conn.	41.8	49.0±	−2	*4.0
Fall River, Mass.	41.7	49.4	1	4.5–5
New Bedford, Mass.	41.6	49.5	3	*4.0
East Chicago, Ind.	41.6	51.0±	6±	3.5
Rock Springs, Wyo.	41.5	42.2	−21	*5.0
Norwich, Conn.	41.5	51.0±	2	3.5
Wallingford, Conn.	41.5	51.0	2	4.0
Cleveland, Ohio.	41.5	50.0	1	5.2–5.7
Lorain, Ohio.	41.5	50.3	12	5.0
Muscatine, Iowa.	41.5	50.0±	0±	6.0
Elyria, Ohio	41.4	50.0±	1±	*4.5–5
Oberlin, Ohio	41.3	50.6	12	*5.0
New London, Conn.	41.3	50.7	2	4.0
Bridgeport, Conn.	41.2	51.5	2	*4.0
Williamsport, Pa.	41.2	51.2	1	†5.0
Warren, Ohio.	41.2	50.0	10	†5.0
Yonkers, N. Y.	41.0	53.0±	5±	4–4.5
Mauch Chunk, Pa.	40.8	51.0	−5	3.0
Shamokin, Pa.	40.8	49.0±	−17±	*3.0
Woodhaven Water Company, N. Y.	40.7	53.3	5	†3.5
Peoria, Ill.	40.7	51.1	2	*5.0
Burlington, Iowa.	40.7	51.5	−3	*5.5
Centerville, Iowa.	40.7	49.5±	−0±	4.5
Lima, Ohio.	40.7	51.4	−4	5.83
Lewiston, Pa.	40.5	51.0±	−5±	4.0
South Pittsburg, Pa.	40.5	52.8	−3	*3.5
Wilkinsburg, Pa. (Penn W. Co.)	40.5	52.8	−3	*3.5–4.5
Dennison, Ohio	40.5	52.0±	−6±	*3.5
New Philadelphia, Pa.	40.5	50.5±	−7±	4.0
Reading, Pa.	40.4	53.6	4	4–4.75
Westmoreland Co., Pa.	40.3	52.8±	−3±	*3.5
York, Pa.	40.0	53.0±	1±	*3.0
Springfield, Ohio.	40.0	51.5±	−6±	*4.0
Quincy, Ill.	40.0	53.0	0	4.5
Dayton, Ohio.	39.6	53.0	−7	*4.5
Marietta, Ohio.	39.5	55.2	0	3.0
Mattoon, Ill.	39.5	53.5±	−11	*3.0
Hamilton, Ohio.	39.4	54.0±	−3±	5
Baltimore, Md.	39.2	56.0	8	*3.5
Gallipolis, Ohio.	38.9	57.0±	−4±	4.5
Belleville, Ill.	38.5	55.5±	5	*3.0

*Depth to top of pipe.
†Depth of trench.

evaporation from the surface during the early stages of the thaw produces additional refrigeration or reduction of temperature at the depth of the water main sufficient to cause freezing. No indication of the existence of such conditions has appeared in the reports received of frozen pipes, and this reference is here made to induce the production of evidence, if any exists, in support of this theory.

BRICKWORK REINFORCED WITH WIRE MESH has been used with a considerable degree of success in India, according to a recent issue of the "Indian and Eastern Engineer." The system consists in using an ordinary 2½ or 3-in. wire mesh in the horizontal mortar joints of the brickwork. It may be utilized to greater advantage both from a strength and water-resisting standpoint, by laying two vertical rows of brickwork about 1½ or 2 ins. apart, tying each horizontal mortar joint of the separate walls with mesh, and in addition connecting the two walls with an occasional strip of mesh. Thus a hollow wall, perfectly tied together results.

A Circuit Breaker for 110,000-Volt Lines.*

Four groups of circuit-breakers were recently installed in the 110,000-volt transmission lines of the Southern Power Co., near Charlotte, N. C. It is claimed that this installation is unique in being the first in which switching apparatus is called upon to break currents of this extreme potential, although several similar plants are now under construction and will shortly be in operation. The 110,000-volt circuit-breakers are designed safely to interrupt any short-circuit current occurring on a system of 120,000-KW. capacity.

A feature of the construction of these circuit-breakers is the isolation of each pole in a separate tank. Each pole is thus entirely independent of the others except for the pull rod which operates the contacts. This rod is released by a tripping mechanism at one side, allowing the contacts to open by gravity. A double-break is made at each pole, spring-seated butt contacts, shown in Fig. 2, making a firm closure. The break, introduced by dropping the contact bar, is 47 ins. long, and occurs in the center of the tank in oil free from any possible sediment or moisture. As gravity assists in making a quick break at normal operation, in case of injury to the apparatus the contacts will tend to automatically open. This is claimed to be an important precaution.

A small double-pole, double-throw switch, operated by the contact mechanism, provides a simple tell-tale, indicating the position of the breaker contacts, by lighting a red or green lamp. The contacts are normally closed by energizing the operating solenoid from a low-voltage local circuit, but may also be hand operated by a lever handle through a simple mechanical connection. Series relays, mounted on suspension insulators and inserted directly in the line, are provided for automatically tripping the circuit-breakers in case of overload. A wooden rod transmits the movement of the relay armature on the suspension insulator to the latch mechanism, providing simple, quick-acting mechanical release effected directly by the line current.

FIG. 1. A GROUP OF 110,000-VOLT CIRCUIT BREAKERS.

The tanks are of boiler steel with welded seams. They are fitted with a thick lining of special insulation and, of course, are filled with transformer oil. The terminals are of the condenser type, to prevent corona phenomena and consequent breaking down at this point of the circuit.

Also 15 circuit-breakers of a type and construction similar to the 110,000-volt apparatus will also be installed by the Southern Power Co. for controlling its 88,000-volt transmission circuits. These breakers will be electrically operated and have their tripping coils energized from series transformers, built in around the terminals and mounted as part of the tank case. This disposal of the series transformers contributes to the compactness and self-contained character of the breaker group, avoiding all external devices and wiring.

*From information furnished by the Westinghouse Electric & Manufacturing Co., Pittsburg.

Preventable Losses by the Municipal Boiler Plants of New York City.

In February of this year Messrs. W. N. Polakov and W. A. Russell, of 95 Liberty St., New York City, presented a general report to Mayor G. B. McClellan, as Chairman of the Board of Estimate and Apportionment, on the decrease in efficiency of coal consumption in the various municipal departments. This report started with a comparison of the increase of population during the years 1905 and 1907 with the increase of coal consumption in municipal plants during the same time. The former had increased about 6% while the latter has risen 42%.

In consequence of this general report Messrs. Polakov and Russell were appointed to investigate, under the direction of the Chief Engineer of the Board of Estimate and Apportionment, the preventable losses in coal consumption in the various plants. It was necessary from the first to concentrate the investigation on the large plants of a single department and those of the Department of Water Supply, Gas and Electricity in the Borough of Brooklyn were selected, as these were the largest coal-burning plants of the city and because their organization was such as to facilitate the investigation of preventable losses. The first report on these plants was presented in September and has just been made available for publication. The following extracts from this report are self-explanatory and need but one comment. The term "efficiency" or "partial efficiency" or "practical efficiency" generally represents the ratio of actual record performance to best attainable performance.

A systematic study of the general efficiency of a great many industrial plants in the United States by specialists has disclosed, according to the highest authority on the subject, Mr. Harrington Emerson, that about three-quarters of all producing concerns are running with an efficiency of not more than 50% that possible, which means that in all these plants, $1 out of every two spent is wasted. According to the same authority, hardly 10% of all the plants are operated with an efficiency of over 75% that possible. Only a few plants—after introducing modern methods—are reaching nearly 100%, having pre-

tically eliminated nearly all losses which can be prevented under the most modern and scientific methods of production and organization.

With a view to ascertaining what results could be accomplished if these methods were applied to the plants of the Municipal Government of New York City, the Board of Estimate and Apportionment engaged the writers early this spring as Consulting Engineers. In accordance with an understanding with you and the Commissioner of Water Supply, Gas and Electricity, we have

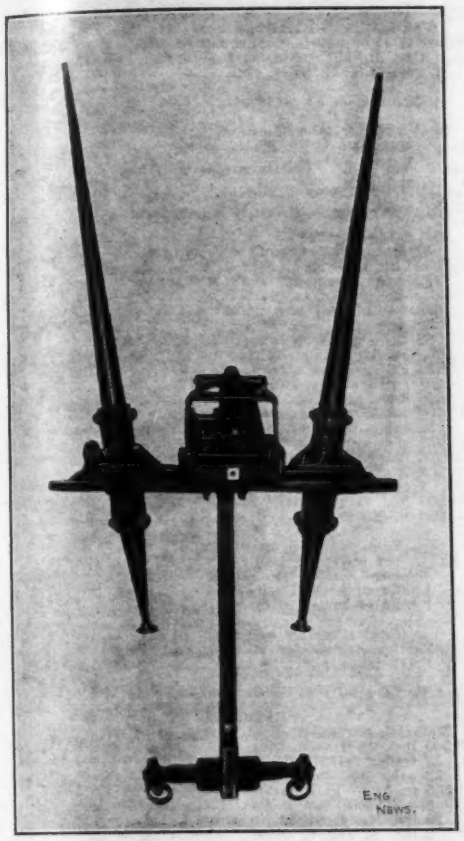

Fig. 2. Terminals of a 110,000-volt Circuit Breaker.

been studying during four months the anthracite-burning pumping stations of the said Department in the Borough of Brooklyn.

Our report shows that the Department's efficiency is slightly above the average of that of ordinary plants, but by applying the most modern and scientific methods of operation and control, the efficiency can be greatly increased.

The pumping stations considered as units, are installations for the purpose of transforming the thermo-chemical energy of coal into mechanical energy at the water end of the pumping engines. The various stages of this transformation stand to one another in relation of a dependent sequence, so that the total efficiency of each one of the plants is a product of the partial efficiencies of the separate stages. Besides being a thermo-mechanical installation, each pumping station is an economic unit, and as the primary purpose of this investigation is a reduction of the unit cost of the final product of these plants (*i. e.*, of the cost of one foot-pound delivered at the water end of the engines) it is necessary to introduce an additional stage—the exchange of money for the thermo-chemical energy of the coal.

Thus we have to consider primarily four stages:

(A) Purchasing of coal, including receiving, storing and handling (*i. e.*, transformation of money into potential thermo-chemical energy).

(B) Combustion of coal under boilers (*i. e.*, transformation of the potential thermo-chemical energy into heat of gases in the furnace).

(C) Utilization of the heat generated in the furnace for evaporating water in the boiler (*i. e.*, transformation of the heat of the furnace gases into volume energy of steam).

(D) Utilization of the volume energy of the steam for performing work in the pumping engines, including conducting of steam through pipes (*i. e.*, transformation of the volume energy of the steam into mechanical work at the water end of the pumping engines).

In each of these four stages there can be differentiated minor or secondary stages which sometimes stand to one another also in a relation of dependent sequence, sometimes again in simple correlation; these will be analyzed immediately in conjunction with the corresponding primary stage.

(A)—PURCHASING OF COAL.—Summary of Findings.—The data given below refer only to anthracite stations.

(1) The absence of a clause in the contract specifying the lowest limit of B. T. U. for anthracite and the impossibility of establishing a standard for B. T. U. leads to an inevitable loss under the present type of contract, this loss being 3.18%. Remedy suggested: Introduction of a new type of contract providing for delivery of so many millions B. T. U. in shape of coal, and calling for bids on the price of one million B. T. U. within specified limits of quality and size of the coal.

Partial efficiency $E_1 = 96.82\%$.

(2) No coal is rejected, though some of it goes below the specifications, because of delays in the reports of the laboratory analyses. Remedy suggested: Increase of capacity of the Mount Prospect Laboratory.

(3) There is no sufficient check on the actual weight of coal delivered through absence of adequate weighing facilities, and it is impossible even to make a rough estimate or guess as to the possible loss. Remedy suggested: Installation of automatic weighing and registering machines of adequate capacity at each plant. The first cost of this apparatus would be probably not more than $12,000, $15,000 corresponding to a loss of 5%, or 6% of one year's coal supply.

(4) The sampling of coal for purpose of analysis seems not always to be quite satisfactory. Remedy suggested: A careful investigation of the methods employed actually by the sampler of the Department, and from time to time an unexpected checking by reliable outside laboratories.

(5) The size of coal (broken) used in 92.5% of the total is too expensive. The loss incurred by the use of broken coal instead of No. 1 buckwheat with a standard heating value of 11,500 B. T. U. per lb. as delivered is 29.91%. Remedy suggested: Change to small size anthracite as soon as possible, possibly under a mutual agreement with the present contractor, as the supply of No. 1 buckwheat on the market is fully sufficient. The only expense to be incurred in connection with such a change would be for new grate bars with smaller air spaces. This item is quite inconsiderable in comparison with the saving effected.

Partial efficiency $E_2 = 70.00\%$.

(6) Total efficiency of first stage: $E_a = 96.82 \times 0.7009 = 67.77\%$.

(7) The total preventable loss in this stage amounts thus to $\$398,346 \times 0.3223 = \$128,400$ yearly.

(B)—COMBUSTION OF COAL UNDER BOILERS.—Summary of Findings.

(1) The absence of a systematic analytical control of the efficiencies of combustion by the firemen leads to a permanent waste through an excess of unburnt combustible in the refuse. This loss as compared with an easily reached minimum standard of 94.7% equals under usual conditions 9.4% of the total amount of coal burnt, or $37,600 yearly. Remedy suggested: Systematic combustion analyses and establishment of a stimulating rating system with records made public at certain intervals, connected with a strengthening of disciplinary enforcement of standard requirements. The cost of a local analytical laboratory at the Ridgewood pumping station will be probably below $5,000 yearly. The standard to be established with the present quality of coal is suggested at 94.7%, this being a rather too liberal standard.

(2) Total efficiency (as to standard) of second stage: $E_b = 90.10\%$.

(3) The total preventable loss in this stage taken individually amounts, thus, to: $\$398,346 \times 0.0940 = \$37,600$ yearly.

(C)—UTILIZATION OF HEAT IN BOILERS.—Summary of findings.

(1) The removal of the scale from the boilers is not done systematically, probably causing large decreases of conductivity of the water heating surface. Remedy suggested: Cleaning boilers according to specially prepared schedules.

(2) The scale forming matter is not precipitated prior to feeding the water to boilers. Remedy suggested: Substitution of a scientifically compounded precipitating mixture according to individual water analyses instead of the secret boiler compound or other unsatisfactory remedies now used.

(3) Analyses of scale disclosed the presence of more than 0.5% of oil. Remedy suggested: Improving operation of present oil separators.

(4) The damper regulators now used are only in the nature of emergency brakes, and to accomplish a higher economy the dampers ought to be individually regulated and the draft regulation of the firemen ought to be controlled. Remedy suggested: Individual study of boilers or boiler groups; establishment of "standard drafts" and installation of both indicating and recording draft gages of some modern type for each boiler.

The decreased efficiency incurred through absence of satisfactory draft standards and draft control shown in tests to be probably $E_c = 86.26\%$.

(D)—CONDUCTING AND UTILIZING OF THE STEAM.—This part of the transformation of the chemico-thermal energy of the coal into mechanical energy is being at present investigated by the writers, and the results of this investigation will be available as soon as the series of studies now in progress is finished.

GENERAL RECAPITULATION.—These data refer only to anthracite stations.

(1) The combined practical efficiency of the first three stages is rather low, namely, $E = E_a \times E_b \times E_c = 52.69\%$.

(2) It is not difficult to reach a practical combined efficiency of 100% thereby effecting a total saving of about $190,000 yearly.

(3) To accomplish this it is suggested that the following steps be taken:

(a) Increase the capacity of the Mount Prospect Laboratory so as to get the results of the analyses before the coal is dumped into the coal piles, and reject all coal falling below requirements; check laboratory's sampling by outside laboratories.

(b) Change as soon as possible the size of coal from "broken" to small size anthracite.

(c) Introduce, as soon as possible, a new form of contract, providing for payment on the basis of chemical analyses.

(d) Establish a small analytical laboratory at Ridgewood Pumping Station, and start systematic individual combustion analyses, introducing at the same time a system of rating firemen by efficiency of combustion. Enforce minimum standard of combustion by disciplinary measures, and raise efficiency by stimulating competitive spirit of men through making public in boiler rooms individual records and plant records.

(e) Establish schedules for systematic cleaning and washing of boilers. Substitute individual precipitating mixtures for each plant, instead of secret boiler compounds and unsatisfactory remedies. Improve operation of existing oil separators.

(f) Install an indicating draft gage and a recording draft gage for each boiler. Establish, through series of tests, most favorable draft conditions, and enforce these standards through strict discipline.

In addition to the above mentioned facts, the writers want to call attention to the utter lack of proper record keeping. The only system of bookkeeping used at present is purely commercial accounting and some forms of rather arbitrary log book recording in the engine rooms. No attempt is made to keep the records in any form allowing a determination of unit costs. No system of storeroom accounting exists which would give an insight into the efficiency of using materials. The coal records and ash records in the log books are quite arbitrary, and the records kept by the coal clerk have no value, except simple accounting; they cannot be used for technical purposes. No records of indicator diagrams are kept; in one plant only have the writers met with an attempt to keep systematic tab on the engines by taking monthly diagrams, but even this attempt did not reach its purpose, as the diagrams are not filed or preserved.

The following specifications for purchasing coal were evolved by Messrs. Polakov and Russell. They are given this peculiar form probably as the Corporation Counsel has ruled that under the city charter such a contract cannot contain any sliding scale for payment. This prevents the use of the familiar form of coal-purchase contract as developed by the U. S. Geological Survey.

SPECIFICATIONS FOR FURNISHING AND DELIVERING BRITISH THERMAL UNITS IN SHAPE OF ANTHRACITE COAL.

Amount of Heat Units in Shape of Coal Required.

(1) The approximate amount of heat units, in shape of coal, required under this contract, the point of delivery and the approximate rate of shipment is as follows:

Point of Delivery.	Approximate Number of B T. U. Required.
.....	.....
.....	.....
.....	.....
.....	.....

POINT OF DELIVERY.

(2) The price stipulated for the coal delivered at..... ..... covers all the work and expense incidental to or connected with the unloading, hauling, storing and trimming of the coal in the sheds or bunkers at the various plants, to the satisfaction of the Engineer.

DEMURRAGE.

(3) It is distinctly understood that the city will not pay any demurrage charges on boats or cars of coal consigned under this contract.

CHARACTER OF COAL REQUIRED.

(4) The sizes of anthracite coal must be as follows:

(a) Egg size passing through 2¾-in. screen and over 2-in. screen.

(b) Stove size passing through 2-in. screen and over 1¼-in. screen.

(c) Chestnut size passing through 1¼-in. screen and over ⅝-in. screen.

(d) Pea size passing through ⅝-in. screen and over ⅜-in. screen.

(e) Buckwheat (No. 1) passing through ½-in. screen and over ¼-in. screen.

(f) Buckwheat (No. 2) passing through ¼-in. screen and over ⅛-in. screen.

(g) Buckwheat (No. 3) passing through ⅛-in. screen.

Not over 10% of the coal delivered must pass through the smaller size of screens.

Point of Delivery.	Size of Coal.	Minimum Number of B. T. U. as Delivered.	Maximum Percentage of Volatile Matter, Dry.	Maximum Percentage of Ash, Dry.	Maximum Percentage of Moisture.
.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....

The size and kind of coal, the minimum No. B. T. U. per pound, the maximum percentage of volatile matter, the maximum percentage of ash, the maximum percentage of sulphur and the maximum percentage of moisture, at the different points of delivery must be as above:

CAUSES OF REJECTION.

(5) Should any coal delivered hereunder contain more than the per cent. of moisture, volatile matter, ash or fewer than the No. of B. T. U. per pound allowed above, or should more than 10% of the coal pass through smaller screens specified for the corresponding size, the coal must be rejected.

WEIGHING.

(6) All the coal delivered must be weighed at the point of delivery on automatic weighing and registering machines having the degree of accuracy of 1%, the weight shown by these machines to be undisputable.

SAMPLING.

(7) Samples of coal as delivered will be taken by a representative of the chemical laboratory of..... All the coal will be sampled at the time of its being delivered to the plant. The sample taken will in no case be less than the total of 100 lbs., to be selected proportionately from the lumps and fine coal, in order that it will in every respect totally represent the quality of coal in consideration. To minimize the loss in the original moisture contents the gross sample will be pulverized as rapidly as possible until none of the fragments exceed ½-in. diameter. The fine coal will then be mixed thoroughly and divided into four equal parts. Opposite quarters will be thrown out and the remaining portions thoroughly mixed and again quartered, throwing out opposite quarters as before. This process will be continued as rapidly as possible until the sample is reduced to such an amount that all of the final sample will be contained in the shipping cans or jars of not less than 2 lbs. capacity, these cans or jars to be sealed air tight.

ANALYSIS.

(8) The sample prepared as indicated above will be forwarded by the representative of the ..... chemical laboratory to this laboratory, where it will be analyzed and tested immediately on receipt, following the method adopted by the American Chemical Society and using a Bomb calorimeter standardized against cane sugar, as obtained from the National Bureau of Standards at Washington, D. C. A copy of the results obtained by such analyses will be mailed to the contractor upon completion of the test and not later than 24 hours after taking the sample. The report of the chemical laboratory will show:

(a) The number B. T. U. per pound of coal as delivered.
(b) Per cent. of moisture.
(c) Per cent. of volatile matter.
(d) Per cent. of ash.
(e) Per cent. of sulphur.

Should there be no question raised by the contractor within 24 hours after receiving the copy of the chemical report, as to the figures shown by the analysis, the sample of the coal will be destroyed. In case the contractor does not abide by the results of this analysis, a second analysis from the same sample will be made, and if the discrepancy between the two analyses will be shown to be 2% or less in the determination of B. T. U. per pound of dry coal, the percentage of volatile matter, the percentage of ash and the percentage of sulphur, then the cost of the first analysis shall be borne by the contractor. In case of a larger discrepancy, the cost of the second analysis shall be borne by the city, and the results of such second analysis shall be regarded as final, with the exception of the per cent. of moisture which in all cases is to be taken from the results of the first analysis, on which basis the number of B. T. U. as delivered should be figured from the number of B. T. U. dry.

BASIS OF PAYMENTS.

(9) The number of heat units in each delivery shall be calculated by multiplying the number of B. T. U. in one pound of coal as delivered, as shown by the chemical report, by the number of pounds delivered, as determined by the automatic weighing and registering machines. This number of heat units will constitute the basis for the corresponding payments.

NOTICE OF SHIPMENT AND ARRIVAL.

(10) The contractor must deliver to the Department the original bills of lading or manifests with each shipment of coal. No coal will be accepted unless such bills of lading or manifests are furnished.

Notice of all shipments shall be mailed promptly to the engineer. The notices shall show the numbers of each weight of the coal, and the date when the same was shipped. These notices shall be accompanied with the original bill of lading or manifest.

CARS.

(11) If cars are to be used they shall be of a suitable size and shape for unloading and shall meet the approval of the engineer.

DELIVERY.

(12) In case of failure on the part of the contractor to deliver the coal at the proper plant or switch in the quantities ordered and at the rate herein specified, within ..... days (Sundays and holidays excluded), after the date of written notice mailed to him by the engineer directing him that shipments of coal are desired, then and in that case the commissioner shall have the right to purchase such quantity of coal in the open market as may be required, and to deduct from any estimate that may be due the contractor the additional cost of the said coal delivered at the dock, railroad station, switch, or other point of delivery, where it may be required, over and above the price stipulated in the contract for coal at the point of delivery.

THE LOS ANGELES AQUEDUCT for the new water-supply of that city is to be completed by May 1, 1912, or a year earlier than has heretofore been announced, according to a statement made by Mr. William Mulholland, Chief Engineer. Articles on the new water-supply system for Los Angeles, which will include an aqueduct 226 miles in length, were published in Engineering News of May 31, 1906, and Jan. 24, 1907.

The Cost of Overhead-Trolley Systems.

By A. D. WILLIAMS, JR.*

The following cost data was gathered in the construction of a short interurban line in the northwestern portion of Ohio, running along country highways. The costs were accurately kept and then were segregated to give the cost per mile. The work was done in the summer time, and during the period of construction there were very few interruptions from the weather. In using figures of this character it is advisable to take into consideration those local conditions which will affect the result. For instance, the character of the ground affects the cost of excavation, or the local rates of wages prevailing. Then there are difficulties in hauling the material. All these and a few other conditions will affect the cost of construction, and for this reason the preliminary surveys should be made sufficient to prevent any costly errors. The data is arranged, in all cases, to show costs per mile of a double-track road.

Cost Per Mile of Overhead Materials.

4,254 lbs. (2 miles) No. 00 trolley wire.	@	$0.175	$754.45
104 trolley ears, No. 00, 15" long....	@	.23	23.92
104 cap and cone hangers, nut lock.	@	.30	31.20
500 ft. 5/16" galv. strand wire.....	@	.012	6.00
500 ft. ¼" galv. strand wire.....	@	.009	4.50
10 feeder clips	@	.09	.90
8 anchor ears	@	.38	3.04
8 Lieb strain insulators, anchor..	@	.11	.88
4 bridle clamps	@	.19	.76
2 Garton lightning arresters.....	@	3.10	6.20
8 wood screws	@	.005	.04
1 lb. friction tape.....	@	.32	.32
2 pins, bond of arresters to track.	@	.02	.04
20 lbs. 0 ground wire.....	@	.06	1.20
20 lbs. No. 0 copper strand insul. wire	@	.18	3.60
25 galv. iron staples.....			.05
2 trolley wire splicing sleeves....	@	.65	1.30
6 lbs. solder ½ and ½.....	@	.24	1.44
1 Brooklyn strain insulator.....	@	.96	.96
Total cost of overhead material..			$840.80

Bracket-Arm Construction.

WITH 37-FT. POLES PLACED IN CENTER.

Material:			
Total cost overhead line material			$840.80
52 pine octagon poles, 12"×8" × 37'.	@	$8.75	455.00
35 gals. graphite paint.....	@	1.15	40.25
4 cu. yds. concrete (1-3-5).....	@	7.50	30.00
104 bracket arms complete.....	@	3.60	374.40
52 mach. bolts, 13×⅝" nut, washer	@	.06	3.12
104 lag screws, ⅝" × 4".....	@	.025	2.60
104 lag screws, ⅝" × 3½".....	@	.025	2.60
400 ft. 5/16" galv. strand wire.....	@	.012	4.80
10 feeder clamps	@	.18	1.80
5 porcelain feeder insulators.....	@	.04	.20
5 galv. lag screws, ½" × 4".....	@	.02	.10
12 drop forged eye-bolts, ⅝" × 16".	@	.09	1.08
7 gals. black paint.....	@	.75	5.25
5 guy anchors	@	1.30	6.50
Total materials			$1,768.50
Labor:			
52 poles, hauled and erected.....	@	$2.65	$137.80
52 poles, painting	@	.30	15.60
Erecting 2 miles of trolley wire.	@	35.00	70.00
Erecting bracket arms.....			30.00
Hauling material			18.00
Clearing foreign wires and poles			93.40
Trimming trees			2.75
Total labor.....			$367.55
Total materials per mile.....		$1,768.50	
Total labor per mile.....		367.55	
Total cost per mile of bracket-arm construction (with 37-ft. poles)..			$2,136.05

WITH 30-FT. POLES PLACED IN CENTER.

Cost of 37-ft. pole construction.....			$2,136.05
Cost of 37-ft. poles, each.....		$8.75	
Cost of 30-ft. poles, each.....		5.75	
Difference on 52 poles.....	@	$3.00	156.00
Total cost per mile of bracket-arm construction (with 30-ft. poles)..			$1,980.05

Cross-Span Construction.

WITH 37 AND 30-FT. POLES.

Material:			
Total cost overhead line material			$840.80
52 pine octagon poles, 12"×8" × 37'.	@	$8.75	455.00
52 pine octagon poles, 10"×8" × 30'.	@	5.75	299.00
8 cu. yds. concrete (1-3-5).....	@	7.50	60.00
2,300 ft. 5/16" galv. strand wire.....	@	.012	27.60
116 eye-bolts, ⅝" × 16".....	@	.09	10.44
70 gals. graphite paint.....	@	1.15	80.50
14 gals. black paint.....	@	.75	10.50
5 guy anchors	@	1.30	6.50
400 ft. 5/16-in. galv. strand wire....	@	.012	4.80
Total materials			$1,795.14
Labor:			
104 poles, hauled and erected.....	@	$2.65	$275.60
104 poles, painting.....	@	.30	31.20
52 span wires erected.....	@	1.50	78.00
Erecting 2 miles of trolley wire.	@	35.00	70.00
Hauling materials			18.00
Clearing foreign wires and poles			138.40
Trimming trees			14.65
Total labor			$625.85
Total materials per mile.....		$1,795.14	
Total labor per mile.....		625.85	
Total cost per mile of cross-span construction (with 37 and 30-ft. poles).			$2,420.99

WITH ALL 30-FT. POLES.

Cost of 37 and 30-ft. pole construction.			$2,420.99
Cost of 37-ft. poles, each.....		$8.75	
Cost of 30-ft. poles, each.....		5.75	
Difference on 52 poles.....	@	$3.00	156.00
Total cost per mile of cross-span construction (with 30-ft. poles)....			$2,264.99

Transmission Line.

Provision was made for two lines of wires, but only one line was fully equipped.

Material, per mile:			
52 cross arms, 4" × 5" × 6', for two 2" pins	@	$0.39	$20.28
52 cross arms, 4" × 5" × 8', for four 2" pins.....	@	.53	27.56
312 2-in. locust pins	@	.025	7.80
52 pairs gal. iron braces, 30" } 52 pairs gal. iron braces, 24" } 598 lbs.	@	.038	22.73
208 carriage bolts, ⅝" × 4¾".....	@	.014	2.91
104 gal. iron lag screws, ½" × 4'....	@	.018	1.87
208 gal. iron lag screws, ½" ×7"....	@	.025	5.20
156 6-in. porcelain insulators.....	@	.46	71.76
2,100 lbs. No. 4 bare copper wire....	@	.175	367.50
52 cable-top glass insulators.....	@	.06	3.12
52 special locust pins.....	@	.03	1.56
65 lbs. No. 4 copper ground wire....	@	.175	11.38
3 No. 4 McIntire splices.....	@	.15	.45
7 gals. carbolized paint.....	@	.65	4.55
900 lbs. barbed wire, galv.....	@	.038	34.20
220 ft. ⅝" galv. strand wire ties....	@	.015	3.30
Total material for one mile....			$586.17
Labor, per mile:			
3 miles transmission line erected..			$103.50
1 mile of ground wire erected....			21.45
1 mile of barbed wire erected.....			21.45
Total labor for one mile.....			$146.40
Total materials per mile.....		$586.17	
Total labor per mile.....		146.40	
Total cost 1 mile of transmission line.			$732.57

FEEDER LINE.

Material, per mile:			
3,500 lbs. 0000 feed wire.....	@	$0.075	$612.50
52 feeder pins.....	@	.20	10.52
52 cable-top insulators.....	@	.06	3.12
550 ft. 5/16" galv. strand wire.....	@	.012	6.60
5 eye-bolts, ⅝" × 16".....	@	.09	.45
20 lbs. No. 4 copper tie wire.....	@	.175	3.50
2 lbs. ½ and ½ solder.....	@	.28	.56
2 splices, 0000	@	.22	.44
Total for material.....			$637.69
Labor, erection of feeder wire.			$45.00
Total material per mile.....		$637.69	
Total labor per mile.....		45.00	
Total feeder line per mile.....		$682.69	

Comparison of Costs, Per Mile.

	Bracket arm.	Cross span 37 and 30-ft. poles.	Cross span 30 and 30-ft. poles.
Trolley wire & poles.	$2,136.05	$2,420.99	$2,264.99
Transmission line....	732.57	732.57	732.57
Feeder line.....	682.69	682.69	682.69
Total	$3,551.31	$3,836.25	$3,680.25

*P. O. Box F, East Liberty, Pittsburg.

THE STORAGE OF ENERGY, for low-pressure steam turbines taking steam from reciprocating engines that run intermittently or under fluctuating load, was noted in Engineering News, Jan. 9, 1908. In this case a "receiver" was designed so that the exhaust steam was blown through hot water, condensing largely and heating the storage water to about 212° F. As the supply of steam for the turbine fell below the demand, the pressure in the receiver tank dropped sufficiently to allow some water to evaporate. The size of the receiver and the quantity of water held was determined by the periods and extent of deficiency of exhaust.

A new design of receiver has now been placed on the market by the American Regenerator Co., of Chicago. In this type the water comes down from a main horizontal storage tank into an annular chamber surrounding a perforated extension of the exhaust main. The exhaust steam controls a valve in the pipe connecting the upper and lower chambers, so that the amount of water supplied to the outside of the spray pipe is always proportional to the amount of exhaust steam passing through it.

The momentum of the steam is sufficient to carry the mixture of water and steam up through a pipe into the upper tank where the mixture is delivered against suitable baffles and separated from the steam.

The hottest water is therefore passed to the surface of the water in the storage tank and the coldest is drawn from the bottom for the spray chamber. The water level in the storage tank is maintained at the center to give a maximum area for the liberation of steam when the stored heat is drawn upon.

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To what extent is municipal work rendered less efficient and more costly by the preference shown to veterans of our Civil War? The 45 years that have elapsed since the close of that struggle have transformed even the youngest of those who saw honorable service from 1861 to 1865 into men far past the prime of life. And yet the statute books of many states demand that veterans be given a preference over all other applicants for positions in the municipal service and make it impossible, in some states, to discharge a veteran for any cause short of crime. As a consequence, many city payrolls have carried for years the names of men utterly incapacitated to do a day's work. That this is demoralizing to the city service goes without saying.

A particularly serious phase of this problem is mentioned by Mr. Guy C. Emerson, M. Am. Soc. C. E., Superintendent of Streets of Boston, in his report for the department year recently closed. Referring to the Veterans' Preference Act, Mr. Emerson says:

> . . . it is particularly unfortunate that men furnished under its provisions are usually of the grade of foremen, thereby lessening to a great degree the efficiency of the subordinates under them.

Needed reforms are beset with difficulties too obvious to need specific mention, but we believe that if the full weight of this drag on the municipal service were known a satisfactory solution of the problem would be found.

Another serious question regarding the cost of municipal work is suggested by Mr. Emerson in the following statement:

> The various executive orders regarding payment to be allowed for holidays reduces the working time of the force by about 10½%, as compared with contract work, and entail upon the department a yearly expenditure of approximately $170,000 for which no service is rendered. The wages of city laborers average about 25% above those paid by contractors for similar work, and entail a further excess cost of about $320,000 per year to the four divisions of this department employing a force of common laborers, viz., the paving, sanitary, sewer and street cleaning divisions.

According to this, city laborers in one Boston city department alone are paid a half million dollars a year more than the same number of men would be paid by contractors, and this on account of holiday allowances, and wages in excess of the open-market price. On whom does this burden fall? Is it in part fictitious? That is, if all the Boston work in question had been done by contract, would the half million named have remained in the pockets of the many taxpayers or would it have gone into the pockets of a few contractors? Moreover, if a half million less had been distributed in wages would the burden on public and private charity in Boston have been increased to any considerable extent? The last question suggests a whole series of others, related to the so-called Living Wage principle, but which we will not inflict on our readers just now.

The points from Mr. Emerson's report which we have cited thus far were advanced by him as partial grounds for his opinion

> that the city laborer is handicapped in the matter of efficiency by circumstances not altogether of his own making.

Mr. Emerson's main thesis, as may be surmised, is that the contract system should be extended and the day-labor system be curtailed at some though not at all points. He reports extensions of contract work made with apparent great advantage during the past year and suggests further curtailments of day-labor work. Thus:

> An analysis of the figures indicates that the street department expends in certain ways a very large sum of money for a purpose that, for the need of a better word, may be designated as *charity* [italics ours—Ed.]. It is worthy of serious consideration whether steps should not be taken to prevent the extension of the day labor system under present conditions and to allow the money expended under it to be economically used for the benefit of the general public according to contract methods.

Misdirected charity and politics of the worst sort, antedating Mr. Emerson's present superintendency of the street department or else beyond his control, have probably had at least as much to do with inefficiency and excessive cost of labor in the department has had the substitution of the day-labor for the contract system of doing work. This constitutes no defense for inefficiency under the day-labor system, but indicates the necessity of going to the root of this and other municipal evils in Boston and hundreds of other cities and securing a sweeping reform in municipal government—such a reform as Mr. Emerson, no doubt, would welcome and aid. We take pleasure in adding, in conclusion, that Mr. Emerson has already been instrumental in effecting a number of reforms advocated by the Boston Finance Commission after its recent exhaustive investigation.

In his paper before the Association of American Portland Cement Manufacturers, reprinted on another page of this issue, Mr. Logan W. Page, of the federal Office of Public Roads, calls very timely attention to the deficiencies of the concrete pavements which have been put down in a number of cities in recent years. The successes of a certain type of this construction on lightly traveled streets of small cities, where heavy trucking is absent and where accumulations of horse droppings and dirt are allowed to form a cushion over the concrete surface has led to the adoption of such pavements in large cities under more severe conditions. The experience in these larger towns has been different, as Mr. Page notes, and wherever the solid concrete pavement has been in place under heavy travel for any length of time, chipping of the edges at expansion joints and at the surface block markings has generally appeared.

The fact is that concrete is altogether too brittle a material to resist successfully the hammer of heavily shod hoofs and its hardness is a breeder of lame horses. To remedy these two defects, Mr. Page proposes a new scheme, which at least has the merit of novelty and which will bear investigation. That scheme is to mix cement and mineral oil in some proportion so that the resulting hardened compound has somewhat of the consistency of the asphalt, sand and ground stone mixtures now common for street paving. If this mixture can be made, so that a substance results with some approach to the strength of concrete and with the resilience of asphalt, a cheap road material is available.

Limited tests recently made in the Office of Public Roads seem to show that the strength of such a mixture is amply sufficient for the needs of a pavement, but so far nothing definite has been determined regarding the wearing qualities of the compound. Oil as an admixture to cement has an unpleasant sound, and it will take considerable experimenting to prove to the average engineer that in time, and probably in a very short time, disintegration will not set in. With the exception of the tests by Prof. Carpenter, of Cornell University (Eng. News, July 4, 1907, p. 16) where a 2% inclusion of either linseed or of engine oil was made in each briquette with no very damaging results, we know of no tests which throw much light on this question. Several sets of tests on the effect of oil baths on more or less hardened concrete have been reported, and although their lessons are somewhat aside from the case in point, the most important of the lot, the report by Mr. J. C. Hains in Engineering News, March 16, 1905, p. 279, comes to one conclusion that is pertinent, namely, that "concrete is more liable to be disintegrated when saturated with oils and fats if not thoroughly set."

All these tests are extremely limited and not at all conclusive, so it is to be hoped that the Office of Public Roads will be able to pursue its investigations until some definite conclusion is reached.

In another part of this issue we have reprinted portions of a report by two "betterment engineers" on the preventable losses in a group of municipal power plants. It is stated, in brief, that the coal actually consumed does only some 50% of the work it is practicable to secure.

A loose contract permits the receipt of fuel having 3% less combustible than bargained for. Inadequate check on weights and quality causes a small increase in the financial loss. The use of lump anthracite instead of fine sizes raises the price of fuel 30% over what it should be. All these losses are on the outside of the power plant. On the inside, careless and indifferent firemen waste 9% of the coal they would burn under good discipline and with proper inducement. Then 10% of the energy liberated from the coal is lost because of excessive boiler scale and poor regulation of drafts. All these values of losses were in plants where the efficiency and character of organization was above the average.

While it is often contended there is greater liability to generally careless operation in municipal plants, contention as to degree scarcely enters here. Poor efficiency, from the causes shown in this report, exists broadly among industrial plants. It is hard to correct it, materially, in small plants and in the larger ones. the improvement is possible only by careful comprehensive study and eternal vigilance. Methods must be overhauled. Each whole organization must be tuned up, so to speak, to work in complete harmony, and men must be kept on their mettle.

The employment of experts, or men possessed of training and experience that gives them special fitness for their work as heads of important municipal departments is not as yet very common in this country. It is, therefore a pleasure to note that representatives of a number of commercial organizations in Philadelphia have united in urging upon Mayor Reyburn of that city

> that the selection of a director of wharves, docks and ferries should only be from those whose previous association with the commercial and maritime business of the port guarantees an equipment for the difficult task, involving, as it should, a broad consideration of many questions affecting both public and private interests.
>
> . . . [and that] while advocating no particular person for the position, fitness to properly fulfill the duties of the office should be the paramount consideration in the appointment of a director for the department.

Such a request is a most hopeful sign of better times in municipal government—all the more so because it was made in Philadelphia.

The announcement in this issue of the death of Dr. Charles B. Dudley will come as a shock to the engineering world, both in America and in Europe. There is hardly a man in the profession so widely known, in so many different

branches of engineering, and who has been at the same time so universally respected and loved.

The engineering profession owes a large debt to Dr. Dudley. He has been in the foremost ranks of those who have been advancing the application of science to industry for more than 30 years past. But in the minds of those who have known him, his professional abilities and achievements are far outweighed by the fine and lovable qualities of personal character which brought to him that most valuable of all assets in this world—a host of warm personal friends.

The Use—and Abuse—of "Cost Data."

There has been a great interest aroused throughout the engineering profession in recent years over the collection and publication of so-called "cost data." The term is a convenient one, signifying the records of the cost of carrying out various classes of engineering work, such records being preferably given in prices per unit of completed work. In all well-conducted manufacturing establishments it is now considered indispensable to keep regular records of the cost of the labor and materials entering into any product. Such cost keeping in factories, properly carried on and properly used, has been the means of effecting enormous savings. It has furnished a guide through which the productive efficiency of many shops and factories has been revolutionized. We would say no word here to lessen the general appreciation of such cost accounting.

Now, just as the old-time factory knew little or nothing of cost keeping, so the old-time civil engineer knew little or nothing of cost data, at least in the shape of systematic records, and certainly nothing in the way of published records available for reference. In fact, the civil engineer of 50 years ago had little need for such data. He was comparatively little concerned with questions of cost. It was conceived to be his business to make his work strong and substantial. It was for the executive heads over him and the contractors who worked under him to deal with questions of the cost of work.

We find remnants of this old idea persisting even to-day. There are still to be found some among the older members of the profession who contend that the engineer should not concern himself with costs and economies except, of course, to the extent that they affect the larger problems that he has to solve. This does not apply, however, by any means to the rank and file of the profession. It is well understood to-day that an engineer is expected to know the commercial side of his profession; to know how to construct not only safely but economically. He should be able to estimate in advance what the cost of given work will be, and his professional reputation will be very largely gaged by the accuracy with which he makes such estimates.

Now, all these matters of the cost of work cannot be evolved from a man's inner consciousness. They are problems which no mathematical formula can solve. They are matters of experience; and as no man's experience is broad enough to cover more than a limited range, we find engineers in all branches of the profession placing high value on published records of cost.

This demand of the profession is reflected in its literature. We believe that Trautwine's "Pocketbook" was the first standard engineering treatise to give special emphasis to records of cost and prices. Within the past ten years, however, cost records in engineering literature have multiplied apace. A description of an engineering work is not considered complete today unless it gives something, at least, relating to the cost of the work with which it deals. Engineering News has taken a foremost part in the collection and dissemination of cost data, and we are continually urging contributors to make their articles more complete with reference to the financial side of the work.

The things we have set forth above are, we assume, pretty well known to the engineering profession. It would not probably have been worth taking space to set them down here, except that what we have to say below should not be misunderstood. We have referred in our heading to the use and *abuse* of cost data. It is because the existing information on costs is susceptible of misuse that some words of warning appear to be needed at the present time. If all the published data on engineering costs were full and complete and reliable, an engineer could make use of them with perfect confidence in his results; but we have the best of reasons for declaring that this is far from being the case. A small proportion of published costs records are complete, in that they give all the essential facts regarding the conditions under which the work was carried on. They are presented in such a way that the careful reader will not misinterpret them, and they are full enough to enable the figures to be used with confidence.

A much larger proportion of published cost data, however, are lacking in some or all of these particulars. The information is by no means without value, but it needs to be used with great caution. The engineer must use it, as he uses many other tools, because he has nothing better to work with; but if he is a wise engineer he will be very careful lest he do himself an injury in handling what may prove a two-edged sword.

If nobody made use of cost data but competent engineers, possessed of that good judgment which is the most valuable characteristic of the competent engineer, there would be no need of sounding a caution concerning the abuse of cost data. These records of cost, however, are spread abroad in published journals and are open to anyone to use. Every engineer of standing and experience is well aware of the existence of so-called "pocketbook engineers"—men who add to a possible smattering of college training the information they have collected from published pocketbooks, and who, on the strength of such an equipment, but sadly lacking experience and good judgment, set out to do engineering work on their own hook. The misuse of cost data by such men often results most seriously for themselves and their clients.

We do not mean by this to undervalue in any respect the importance of published information, whether in pocketbooks, in more ample engineering treatises or elsewhere. What we do wish to emphasize is the fact that some breadth of information and sound judgment are absolute prerequisites to successful work as an independent engineer; and if a man lacks these he is likely to bring serious discredit on himself and on the profession in attempting to carry out engineering work.

There have been some conspicuous examples within recent months of the abuse of cost data. A year or so ago a number of amateur engineers were rushing into print in the newspapers to criticize the work on the Panama Canal. The public was deluged with authoritative references quoted by these gentlemen to show how extravagantly the work was being carried on, and how much more cheaply it could be done if only the schemes of this, or that, or the other party were adopted.

The trouble with such amateur engineers is that they fail to understand the limitations in the use of practically all published cost data. They lack the practical knowledge that enables them to appreciate the great differences which often may exist between two different pieces of work and the great influence which differences in conditions that seem to them comparatively insignificant may have upon the cost of different pieces of work.

Cost records are extremely useful to the designing engineer; to the estimating engineer; to the contractor in making plans and estimates and following the work that he has in hand; to the superintendent engineer in following through a piece of construction. But when such records are made the basis of published criticisms of engineers or contractors, it is time to call a halt. We do not say that such criticisms may not be justified. We do say that the basis on which such criticisms are made is wholly insufficient to warrant any one in forming a judgment.

We do not undervalue either the possibilities which comparative cost figures may offer in the way of critical analysis. It is possible, for example, that some day we shall have municipal accounting on so uniform a basis that it will be possible to usefully compare the cost of street cleaning in one city with that in another, or the cost of pumping water in one city with that in another, and so on and all through the line of municipal housekeeping.

At the present time, however, the differences in methods of bookkeeping and accounting, and the differences in conditions, are such that without a most painstaking and thorough comparison and analysis of all these differences, no one is justified in making use of comparative cost data, without other supporting information, to hold any engineer or contractor up to public criticism.

A similar caution ought to be observed in the use of such cost data as is obtained in manufacturing plants or in other industrial operations. Because the books of a certain railway show a very low cost per ton-mile of freight moved, as compared with another rival road, it does not at all follow that the road showing the low cost is well managed and the other one poorly managed; so, too, with other figures, such as the cost of locomotive repairs, of fuel, of water supply, etc. In industrial plants, too, the inquisitive director who tries to compare the cost sheets of his own factory with the cost of another may perform a very useful work, and, on the other hand, if he lacks good judgment and discretion he may do serious injustice to a competent manager.

LETTERS TO THE EDITOR.

Bore Holes from the Surface to Furnish Fresh Air and Supplies to Miners Shut Off from the Shaft by a Mine Disaster.

Sir: In connection with the recent disaster at the Cherry mine in Illinois, it has frequently occurred to the writer that some one is very lax in providing safeguards to protect the lives of the miners.

It has been the record of every disaster of this character, that a large number of miners have been entombed; and while they were not killed outright from the force of the explosion or fire, they died of starvation or from the deadly black damp. Had these survivors been furnished with a pure air supply, food and water, there is no question but what hundreds of lives might have been saved in the last few years.

In the Harwick mine explosion in Pennsylvania, a large number of miners literally starved to death and the same thing happened at Monongah, W. Va., where between 350 and 450 miners lost their lives. Now comes the Cherry mine disaster. There have also been dozens of instances where anywhere from one to twelve men have been killed. Considering the inexpensive method which might be employed to safeguard the various mines, it would seem that our lawmakers would pass such measures as would compel the mine operators to adopt them.

I noted an article in one of the mining papers recently where the editor suggests installing telephones in mines so that the entombed miners might get into communication with the outside world and be able to give information as to their exact condition, the condition of the mine, etc. This would be some safeguard and guide for the rescuers, providing the telephones were installed in such shape as to prevent the explosion from destroying the wires, but the ideal plan would be to sink bore-holes from the surface at stated intervals, running along the main entries and tapping the main stations in the mine.

These bore-holes should be cased with iron pipe from top to bottom and of sufficient size so that in case of accident they could be used for supplying various sections of the mine with pure air supply, food, water and communication with the entombed miners.

It would hardly be possible for an explosion to destroy a bore-hole, as these explosions do not usually occur in the main entries of the mines. They are usually in some part of the mine that has been abandoned and with no outlet for the gas which accumulates. This is largely responsible for the explosions that take place. If bore-holes were sunk into the old workings they would provide an outlet for the dangerous gases and black damp.

Had this provision been installed in the Cherry mine as well as the others and fresh air furnished to the miners, a large number of lives could have been saved and I think that the mining journals and the public at large should make a strenuous effort to have such measures passed as would safeguard the men who work underground.

These disasters fall on a class of people who are dependent on their daily labor for the livelihood of their families and the loss of the bread-winner under

these circumstances produces conditions so deplorable that they can hardly be imagined by people who are in good financial circumstances.

The prestige of your paper carries great weight and the suggestion coming through the columns of your paper would receive the sanction of a great many people of influence. You will readily appreciate the advantages of a plan of this character and I trust that you will act upon it.

The idea is not original with me, as I have seen this plan used in ventilating mines. Where they could not get a pure air supply to the face of the entries which they are driving, by ordinary means from a fan, they drilled holes ahead of the entry and when these holes were tapped they caused a great current of air to flow through the entries which carried out the smoke, gas, etc., back and up through the hoisting shafts.

It was by observing these that the idea occurred to me that bore-holes of this character would be the ideal method of preserving the lives of entombed miners.

Yours very truly,

W. T. Kershner.

Washington Court House, Ohio, Dec. 2, 1909.

[Under some conditions, as for example, a shallow cover over a coal seam, so that the necessary bore holes would be short, our correspondent's plan might have merit. It would be difficult, however, to frame laws so as to require such bore holes where conditions were favorable and permit their omission where the conditions forbid them. Besides, in many mine disasters, the explosion itself or the gas which follows in its wake quickly destroys all life in the mine.

Certainly such disasters as that at the Cherry mine deserve the most careful attention from mining engineers, so that they may plan intelligently for the installation of safeguards.—Ed.]

Heavy Rainfall and Floods in the Dominican Republic, Haiti, W. I.

Sir: With reference to the recent flood here, a few facts may be of interest. The heavy rains began on Nov. 2 and continued until Nov. 14, 1909. The actual records at Monte Cristi and Puerto Plata (see map), two nearest stations not washed out, are as follows:

Nov.	Monte Cristi, ins.	Puerto Plata.
2	1.8	
3	...	
4	0.9	
5	2.1	
6	1.5	Nov. 2 to 12, 81 ins.
7	2.2	
8	1.9	
9	0.4	
10	2.1	
11	3.2	
12	1.0	
13	0.4	
14	0.1	
	17.6	

The entire rainfall during the year up to this time was 21 ins.; that of 1908, 33 ins.

Two other stations ten and twenty miles, respectively, up the valley of the Yaqui, and both washed out, show a rainfall of 20 and 14 ins. from January to October, inclusive.

The maximum intensity measured during the storm was on Nov. 5, when the gage registered 1.9 ins. in one hour. There was a high wind, probably to some extent vitiating the accuracy of the observation. Other observations on intensity taken at Monte Cristi, are as follows:

Date.	Duration, h.	m.	Quantity, ins.	Intensity, ins. per hr.
Aug. 14, 1908.....	0	27	.75	1.7
Aug. 26, 1908.....	0	08	.39	3.0
Aug. 28, 1908.....	0	16	.55	2.1
June 6, 1909.....	2	00	2.10	1.1
Sept. 27, 1909.....	0	20	.67	2.1
Nov. 11, 1909.....	15	20	3.30	0.22

The above observations were carefully taken but do not necessarily represent maximum values, no automatic register being used.

The Yaqui River is 130 miles long and has a drainage area of 2,700 sq. mi., both estimates being somewhat approximate. The rainfall in the upper portion was undoubtedly greater than the lower or Monte Cristi section.

The Yaqui River is a steep, torrential stream until it reaches an alluvial plain in lower reaches. Through this plain it winds for 75 miles, varying in width from 1 to 10 miles. This plain is from 3 to 25 ft. above the normal river level and is a network of caños or old river beds.

Fearing floods the natives built their towns as far from the river as possible without leaving the plain, though only the lowlands close to the river are sufficiently moist for cultivation by the crude methods employed. The unprecedented rainfall of more than 20 ins. in a week inundated the whole plain to a depth of 5 to 15 ft., utterly destroying all the towns, farm houses, fences and crops and drowning nearly all the domestic animals.

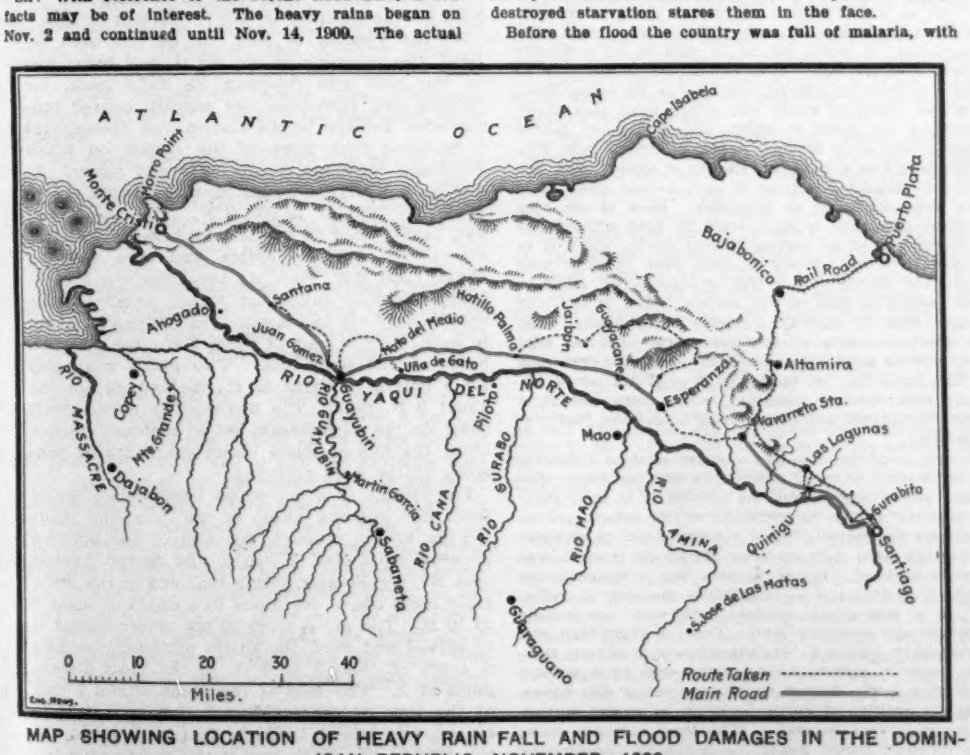
People climbed to the tops of houses, trees and hills and were rescued by boats or waited for the flood to subside. Apparently not a large number have been drowned, but the worst is yet to come. The poor people live from hand to mouth and seldom have as much as $1 in money for a whole household. With crops and animals destroyed starvation stares them in the face.

Before the flood the country was full of malaria, with very little medicine available. With miles of newly-formed swamps filled with decaying animals and mosquitoes and some 15,000 people without bread or shelter or money serious epidemics are sure to rage. The towns destroyed are Guayacanes, Jaibon, Guayubin, Santa Ana, Juan Gomez and Las Aguas. The area flooded is probably not less than 300 sq. mi.

The minimum river discharge during 1908 and up to Nov. 1, 1909, was 1,100 cu. ft. per sec., the maximum 17,000 c. f. s. on Oct. 26, 1909. Even an approximate estimate of the present flood discharge cannot be made, though it must have been several times the above maximum.

J. L. Mann,
Director of Irrigation, Dominican Republic.

Monte Cristi, Nov. 22, 1909.



MAP SHOWING LOCATION OF HEAVY RAIN FALL AND FLOOD DAMAGES IN THE DOMINICAN REPUBLIC, NOVEMBER, 1909.
(Dotted lines show trail taken to reach devastated district.)

Facilities for Making Searches at the New York Engineering Libraries.

Sir: Referring to your editorial of the 9th inst. concerning the Engineering Societies' reference library, the writer would like to do a little "wondering" too. He wonders whether all users of the library of the American Society of Civil Engineers appreciate that for a small sum to cover the time in making it, a library search can be had on any subject, thereby saving a great deal of valuable time.

This may also be a feature of the Engineering Societies' library. If so, and if the same promptness and courtesy exists as in that of the American Society, the institution must indeed be a real boon to busy people.

Yours truly,

Mason R. Strong.

7 Wall St., New York, Dec. 10, 1909.

[Our correspondent does a useful service in calling attention to the great value of the American Society of Civil Engineers' library to the engineer located in a remote section where library facilities are lacking and even to the engineer who has a library at his disposal but who needs a broader source of information. These searches, undertaken for the mere cost of the time spent by the library attendants, are available, like the ordinary use of the library, to engineers generally, whether members of the society or not.

We are informed that the staff of the Engineering Societies' library in the 39th St. building also makes searches for engineers outside of New York City for a small fee.—Ed.]

Feed-Water Distributor for Locomotive Boilers.

Sir: The article on the Seddon boiler-feed device in your issue of Dec. 2 has been carefully noted and I am very much pleased with the manner in which the matter was presented in your paper.

Since writing you in relation to the performance of this device, we have secured additional data in the matter, and I have made several discoveries in connection therewith. These have placed the device in a more attractive light to railways troubled with bad water than the results we had obtained as a preventive for leakage at the tube plates, and had I known that this matter was to be published at this time, I would have furnished you with the additional information, thereby making your article more complete and more interesting.

I would state that we have equipped several engines on neighboring roads which are troubled with bad water, causing the boilers to foam. Engines equipped with the feed distributing device working alongside of engines equipped with the old method, clearly demonstrated beyond a doubt that boilers having feed-water delivered by water sprayed upward in the manner you described, absolutely stopped all trouble due to foaming. This matter was gone into thoroughly, and with the result that the road in question decided to standardize the device, putting it on all of their engines.

After getting information covering this new feature, I investigated the matter further personally, as to why these results were obtained. The only theory I can deduct from my investigation, is that on account of the water being sprayed in an upward course, held in suspension, surrounded by steam of a high temperature, the water is broken into small particles, and the heat is so intense that all solids or foreign matters are immediately precipitated and separated before they mingle together.

I examined several engines on which the device had been in service for a year or more, and I found heavy deposits of mineral or organic matter on top of the dry pipe, on which part of the spray of the feed-water had fallen, proving conclusively that the above action must take place.

We are now equipping our engines with a pan placed underneath the spray pipe; this is large enough to catch the spray water and allow of the depositing of any foreign matter, thus preventing it falling and mingling with the tubes.

I think the above facts will be interesting, and you may wish to publish them as valuable information for the readers of your publication.

Yours very truly,

C. W. Seddon.

Supt. of Motive Power and Cars, Duluth, Missabe & Northern Ry.

Proctor, Minn., Dec. 14, 1909.

Notes and Queries.

If the inquirer for a definition of mechanical filtration will send his post-office address an answer to his letter will be sent to him.

A reply to an inquiry as to the relative strengths of two apparently similar boilers has been returned because of a wrong address furnished us.

The Possibilities of Portland Cement as a Road Material.*

By LOGAN W. PAGE.†

Lime-cement concrete is the oldest road material of which we have any record. The Roman roads, which were of this type of construction, are the only ones which have endured for any great length of time. The Appian Way, which is undoubtedly the best type of Roman road, was begun by Appius Claudius 312 years B. C. and parts of it are in a remarkably good state of preservation to-day. We know perfectly well that any of our modern Portland cements are far superior in strength and durability to the lime mortar used by the Romans, and yet I have never seen a road built of Portland cement concrete that I considered altogether a success. There are two characteristics of Portland cement concrete which, in my opinion, bring about the failure of roads constructed of it. They are, first, the tendency of concrete, where exposed as in a road surface, to develop shrinkage cracks. These cracks are generally parallel to the road and increase in size as time goes on. The second characteristic which brings about failure is the ease with which concrete spalls along the margins of cracks. I have never seen a concrete road fail through what I thought was expansion, but it is the general practice to place expansion joints at right angles to the line of concrete roads at frequent intervals, and the road suffers much from spalling at these joints.

It is perfectly apparent to any one who has made a study of the subject, that there could be no better form of road construction, at so low a cost, to meet only automobile traffic conditions than a cement macadam road. The most durable types of rock could be used as an aggregate, which would give maximum life to the road, and it would be practically dustless. So apparent is this, that in the endeavor to use Portland cement in road construction much ingenuity and refinement has been resorted to, but with the exception of a few isolated cases, real success has not been attained.

It might be appropriately asked, Why have the Roman roads stood varying traffic conditions for so many centuries? I believe that a consideration of this point might be helpful in meeting our present conditions.

In the construction of Roman roads of the best type, a trench about 3 ft. deep was excavated the entire width of the road, and wherever poor material was present it was removed and replaced by suitable material, and the whole subgrade was thoroughly compacted by ramming. Generally four distinct layers were placed in these roads. The bottom course, or *statumen*, was composed of two courses of stones placed in lime mortar. On top of this was placed the *rudus*, or rubble, which consisted either of broken stone, or when available, broken bricks, potsherds, etc. When the latter composed the aggregate, more lime was used in the proportion of 2 to 5. This course was very thoroughly rammed, and was usually about 9 ins. thick. The third course, or *nucleus*, was composed of old building material such as brickbats, broken tiles, etc., mixed with lime in proportion of 1 to 3. This course was not rammed and the lime was mixed hot. Above this course came the top or wearing surface called the *summum crustam*, which was made of blocks of flat stone set in mortar and fitted together with great refinement. It can be seen that the third layer, or *nucleus*, was much softer than any of the others, and was placed purposely below the top layer which was designed to take the wear of traffic.

This type of road was undoubtedly the result of much experience. There are four distinct features which I consider worthy of the fullest consideration. First, an absolutely secure foundation was always obtained; second, a resilient or cushion layer was placed just beneath the wearing surface; third, the four layers composing the road had different coefficients of expansion which would probably preclude the development of definite lines of stress brought about by contraction; fourth, the exposed or wearing surface was composed of a material which would not only withstand the wear of traffic, but atmospheric conditions as well.

We frequently hear the statement that the Roman method of road building is a lost art, and that we cannot build roads to-day of a similar character. This is altogether a mistake. We could not only build similar roads, but roads which under the same conditions would be more durable. A road of the Roman type under modern city traffic conditions would last only a few years, and would probably cost $250,000 a mile to build. The traffic they were subjected to consisted of light vehicles and unshod horses, and the fact that unshod horses were used leads one to believe that an earth cushion was probably maintained on the surface of these roads as otherwise a horse would go lame after 50 or 60 miles of travel. The portions of Roman roads that we find intact to-day are those which have either been subjected to very light traffic or have been completely covered up with earth for long periods of time. In most cases we find only portions of the foundations.

The nearest approach we have to the Roman road to-day is the best type of paving brick, laid on a concrete foundation with a 2-in. sand cushion, and this type of road suits automobile traffic admirably, but is very hard on the feet of horses. As far as I have observed the concrete foundations both for brick pavements and asphalt streets rarely crack except from faulty foundations. The contraction cracks, therefore, I believe are due to no fault in the cement, but to the great range of temperature to which the road surface is subjected, and the fact that it is generally laid during the warmest season of the year, when expansion is greatest. This view is further upheld when one considers that concrete floors and pavements laid on earth foundations inside of buildings rarely crack.

Whether this view of the matter is correct or not, we know that concrete roads at present are not satisfactory, and our next consideration is whether they can be made so. Concrete has been almost universally adopted as a foundation for almost all types of heavy traffic pavements. It gives perfect satisfaction when protected from direct exposure, and whether methods of construction, or treatment, can be devised by which concrete can be used as a wearing surface for roads is a matter for investigation.

It is my belief that in most concrete roads the concrete is too uniformly mixed and too homogeneous in composition. This may account, in a measure, for the development of shrinkage cracks, where the surface is exposed to a great range of temperature. Concrete is also too unyielding to the blows of traffic and too brittle, both of which characteristics facilitate spalling. It seems to me that a pavement can be made which, to some extent, will obviate these undesirable characteristics, and I would suggest the following general specifications:

About 6 ins. of number one broken stone mixed with the screenings below ½-in., thoroughly rolled with a steam roller as a foundation course. On top of this, spread a uniform layer about 1 in. in thickness of rather dry cement sand mortar. Over this course of mortar at once spread about 3 ins. of No. 2 stone, which should immediately be rolled with a steam roller until the cement sand mortar rises flush with the surface. Such a road as this, I believe, would have many advantages. It could be opened to traffic within a short time after completion; it would not be as rigid as an ordinarily mixed concrete road. I do not believe it would be as likely to crack as ordinary concrete, as the stones forming the aggregate would rest firmly upon each other, receiving the blows of traffic, and the cement mortar only acting as a binding matrix. Further than this, there would be a minimum amount of cement used, and no two horizontal sections of such a road would have the same coefficient of expansion. Rock of the very highest resistance to wear could be used without any consideration of its natural binding power, which is so important in the ordinary macadam road. Another most important feature of this type of construction would be the absence of dust on the surface, which is so much sought after by highway engineers at the present time. It would also give an excellent surface, not too slippery nor too noisy. Most important of all, however, such a road would not cost more than 10 or 15 cts. per sq. yd. more than ordinary macadam, which extra amount is about the annual cost of spreading bituminous dust preventives.

I have mentioned this type of construction as a possible cheap method of using concrete in road building. Another way of approaching the problem is to treat Portland cement so that its brittleness will be reduced and its resilience increased. This I believe, would be of great advantage, even if in so doing the tensile strength was greatly lessened. It can be seen that a material like asphalt, which meets so successfully the wear of traffic, is of a semi-plastic nature, with very low tensile strength and no elastic limit. Alone, a slight blow will permanently deform it. Its adhesiveness to mineral matter, however, permits its being tempered by a mineral aggregate to the desired consistency. It is also known that the addition of Portland cement to asphalt surface mixtures is very desirable. With these points in view, the Office of Public Roads has begun an investigation to ascertain the practicability of mixing semi-asphaltic base oils with Portland cement concrete, with the object of obtaining the desirable properties of both the cement and asphalt. Up to the present time, our results have been somewhat encouraging. We have succeeded in making mixtures of as high as 20% of oil, and both the 7 and 28-day tests for toughness and tensile strength showed a regular increase. Briquettes with 5% additions of oil broke in tension at 230 lbs. after 7 days in soak, and 296 lbs. after 28 days; with 10% oil, 228 lbs.; with 15%, 246 lbs.; and with 20%, 203 lbs., all after 28 days. The results obtained under impact were practically parallel with those under tension. Increased proportions of oil retarded both the initial and final set in increasing amounts; the tensile strength and toughness were also reduced, but not in like proportions. It has been shown that concrete immersed or mixed with animal and vegetable oils disintegrates and, of course, this may be the case with petroleum. It is my intention to continue this investigation until the several points under consideration have definitely been settled. I might mention further that parallel tests were made with tar and cement, but the results were practically all negative.

If it is found that cement can be mixed with asphaltic base oils, and increased toughness obtained, I believe that the value of cement as a road building material will be very much increased. The matter of mixing the oil is very simple, and can be conducted in an ordinary concrete mixer. All that is necessary is that the cement be thoroughly wet before the oil is added. On account of the lime present the oil quickly emulsifies and is evenly distributed. Mr. Moyer has suggested that the addition of hydrated lime would permit of larger proportions of oil, which I believe will prove to be the case. I further believe that concrete mixed in this way will be impervious to water.

While a laboratory investigation of this nature is very interesting and instructive, yet no final results can be obtained until an actual service test is made, and it is my earnest hope that in the near future I may be able to make satisfactory arrangements for one or more cooperative service tests, as the appropriation for the Office of Public Roads cannot be used for the purchase of material and labor for road building.

*Paper read before the Association of American Portland Cement Manufacturers, New York City, Dec. 15, 1909.

†Director of the Office of Public Roads, U. S. Department of Agriculture, Washington, D. C.

A Peculiar Penstock Accident at the Lac Du Bonnet Plant of the Winnipeg Electric Ry.

In our issue of Dec. 2 we made brief note of an accident, on Nov. 23, at the Lac Du Bonnet hydro-electric plant of the Winnipeg Electric Ry. A correspondent has sent us an account of the accident, of the temporary service furnished to the city which depended largely on this one plant and of the means taken to expedite repairs and to resume full service.

The plant has a rated capacity of 30,000 HP. in nine units, each unit consisting of a single generator coupled to four McCormick wheels. The penstocks are only some 35 ft. long and the head on the turbines is only a fraction of this.

On the evening of Nov. 23, as has been related, the penstock of the No. 7 unit burst just as the load was reaching its daily peak, for lighting and rush-hour car service, caused considerable damage to the station and necessitated a complete shut down of the system on which Winnipeg depended for its light and power. At 4.38 p. m. everything was running smoothly with a station load of 12,700 KW. The No. 7 unit had been placed in service, in parallel with the others, six minutes before and was carrying about 1,500 KW. load. At this time the switchboard operator called for "more gate" on this unit to care for increasing load. When at about ⅞ gate, with a load of 2,000 KW., the penstock burst on the south side. Two plates gave way for a length of about 12 ft., making an opening about 9 ft. high. The bed casting of the draft chest on the downstream set of turbines cracked along the line of rivets where the ruptured penstock plates were attached.

The volume of water which immediately issued from this opening burst in the door and made a huge breach through the wall of the building between units Nos. 7 and 8, and flowed directly onto No. 8 generator, filling that end of the generator room above the doors to a depth of some 8 to 10 ft. The great force of the water caused it to spread and flood the entire building, reaching a depth of from 2 to 4 ft. in the most distant parts of it. The men at the gates of No. 7 unit at the time of the accident had barely time to escape, and one of them, in fact, was swept out the door at the north end of the building by the rush of water. Credit is due to the employees for their coolness in promptly throwing the load off the machines and preventing the destruction of all of the machinery in the building.

The rush of water was so great that it was impossible for the employees to reach the governor hand wheels to close down the turbines by way of the floor, but they were lowered down by ropes from the windows of the wheelhouse roof and in 4 to 5 ft. of water managed to stop all wheels except units Nos. 8 and 9, which could not be reached owing to the tremendous volume of water which rushed through and completely over them. These two machines were running under water for a couple of days. An attempt

was immediately made to lower the headgates, but the flow of water through the burst penstock made such a pressure against the gates that they could not be stirred.

In Winnipeg the first intimation of trouble was the loss of current. Cars were just filling up for the evening rush and were left stranded on the street. All lights and power were off, and at first the general public were under the impression that there had been a serious fire. The company has a private telephone to Lac Du Bonnet, but as the whole operating staff was busy there was no one to answer calls. As soon as it was realized that the interruption of the service was more than trifling the manager issued instructions to have the old steam plant (used before the Lac Du Bonnet power station was built) put into commission at once. Three years previously this plant had worked to an overload capacity of 8,000 HP., but although the precaution had been taken of keeping up steam sufficient to turn the wheels over once a day, things there were naturally not in condition to get back to former operation, and in any case the power at full capacity was far below the present requirements of Winnipeg. The best that could be done on the first night was to furnish a partial lighting service, and in the early hours of the morning to take on the street railway.

Two hours after the news of the serious nature of the accident reached Winnipeg, the manager and chief engineer of the company were on the way to the plant in a special train. This plant is 65 miles from Winnipeg and only a few trains run in a week. The station is some nine miles from the railway and supplies have to be hauled over a corduroy road. The condition of affairs at the station was found serious, the attempts to shut off the water having entirely failed. The only means which could be devised for stopping it, as reported, was driving piles in front of the headgates, and sheeting these in front with brush and canvas and bags of sand, by which means the water was eventually checked sufficiently to enable the headgates to be lowered.

The water was drained from the power-house sufficiently by the following evening to allow examination of the machinery, and work was at once started to get some of the generators again in operation. On the evening of Nov. 29, less than six days after the accident, one generator was sufficiently dried out so that about 1,500 KW. of power was supplied to Winnipeg to assist the over-burdened steam plant, where one or two minor accidents had been caused by the heavy overload.

The system followed in the city was to furnish as full a car service as possible from 6 to 8.30 a. m. and a lighting service on as many circuits as possible. From 8.30 to 4.30 the available current was placed at the disposition of users of commercial power. From 4.30 p.m. to 7.30 p. m. it was changed for cars and light; from 7 p. m. to midnight a full lighting service was given, and from midnight to 5 a. m. commercial power was furnished. This system was adopted at the request of the Board of Trade and the City Council, as it was represented that this would allow the factories to run on practically full time. The public generally took the accident good humoredly.

At Lac Du Bonnet, all the cables in the building, from the generators and switchboard to the transformers and the switch cells, being in ducts below the floor were found to be entirely soaked with water, and temporary wiring had to be installed to get the generators into operation after they had been dried. Work was also hampered by broken steam connections and other similar damages. In inspecting and testing the generators it was found that the most serious damage was near the point where the break occurred. Those farthest away were the least damaged. One generator had to be partially rewound on one side where it received the full force of the water, which tore off the insulation of its windings.

In seeking the cause of the accident an examination was made of the gate rigging of the No. 7 unit. It was found that five teeth had been stripped from the hand-wheel pinion on the governor. It is presumed that when these teeth stripped the gates closed suddenly and caused some water hammer which burst the penstock or led to secondary actions.

The Lac Du Bonnet plant has had a good record up to the time of this accident. In the four years of its operation, it is reported, the total duration of shut down has been 25 minutes.

The early development of the plant was under the direction of Mr. H. L. Cooper, of New York City, but he later withdrew and the work was finally completed by Mr. F. S. Pearson, of New York City. At the time of completion full tests were made and more severe conditions were then imposed than would accompany the sudden closing of the turbine gates through stripping of the governor hand-wheel pinion teeth. No difficulty has ever been experienced in closing the double head gates under the heaviest overloads.

AN EXPLOSION OF BLASTING POWDER at Frostburg, Pa., Dec. 17, wrecked a two-story building owned by the Rochester & Pittsburg Coal & Iron Co. Four persons were killed.

A FIVE-MASTED SCHOONER WAS WRECKED Dec. 13 off Wimble Shoals, 25 miles north of Cape Hatteras, and all but one of her crew of 15 were drowned. The wrecked schooner was the "Governor Ames," bound from Brunswick, Ga., to New York City with a cargo of railway ties.

THE HYDRAULIC DREDGE "PORT ANCON" sank Dec. 11 between Frying Pan Shoals and Point Lookout in Chesapeake Bay. Five men were drowned. The "Port Ancon" was owned by the American Towing Co., of Baltimore. She was 140 ft. long with 40-ft. beam and 12-ft. depth.

AN UPHOLSTERY FACTORY BURNED in Philadelphia, Pa., Dec. 16, and five employees and one fireman lost their lives in the flames. The fire occurred in the evening and, soon after its discovery, the lights went out making it difficult for the employees to escape. Those killed were working on the fifth floor of the building when the fire broke out.

A four-story frame tenement and lodging house in Cincinnati, Ohio, was destroyed by fire Dec. 14 and seven tenants were killed. The fire started early in the morning while all the occupants were asleep.

THE REAR COLLISION AT NORTH EAST, PA., Dec. 14, between two passenger trains on the Lake Shore & Michigan Southern Ry., noted in our last week's issue, has been ascribed by the coroner's jury to negligence on the part of two trainmen. The verdict is as follows:

We find that the cause of the collision was due to the gross negligence of George J. Sleight, flagman of Train 10, in failing to give the proper signal to Train 26. We further find that M. L. Burger, engineer of Train 26, contributed to the cause of the collision, in failing to bring his train to a stop before passing signal No. 75-2, which was set against him and which he failed to see owing to the smoke and snow, although he knew full well its location and neglected to follow the safe course and bring his train to a full stop, as provided for in the rules of the company.

SEVERAL SERIOUS RAILWAY ACCIDENTS have occurred during the past week. Passenger train No. 11 on the Southern Ry. was wrecked early in the morning of Dec. 15 at Reedy Fork trestle ten miles north of Greensboro, N. C. Twelve persons were killed and 25 others injured. The train consisted of a baggage car, an express car, three day coaches and two sleeping cars. It was derailed about 200 ft. from the trestle. The locomotive and the baggage and express cars crossed the trestle in safety but the five coaches broke loose and overturned, falling from the trestle into the stream below. The accident is ascribed to a broken rail.

A passenger train on the Central of Georgia Ry. collided with a passenger train on the Macon & Birmingham Ry. at Harris, Ga., Dec. 17. Four persons were killed and many others were injured.

A west-bound passenger train collided with a freight in the Lake Shore & Michigan Southern Ry. yards at Cleveland, Ohio, Dec. 18. Five trainmen were killed. The accident is ascribed to the obscurement of signal lights by a heavy snow storm.

A 25-YEAR STREET RAILWAY FRANCHISE EXtension at Kansas City, Mo., was voted down by about 7,200 majority on a referendum election held Dec. 16. The present franchise of the Metropolitan Street Railway Co. has 16 years to run and there was much opposition to extending it for an additional 25 years. The company claimed that an extension was needed to enable it to meet bonds soon coming due and to provide for improvements. The company offered 6 tickets for 25 cts. bought on its cars or 25 for $1 bought in any one of 22 drug stores.

THE BURSTING OF A 36-IN. WATER MAIN at Chicago in the early morning of Dec. 11 caused considerable damage to property and discomfort to people in the neighborhood by the flooding of basements occupied by families. In some cases the water reached a depth of nearly 6 ft. and there might have been loss of life but for prompt action of the police and others in rescuing imprisoned persons. The leak occurred at the intersection of Lowe Ave. and 35th St., and caused the washing out of a large hole in the street and sidewalk. After the water had been shut off, fire engines pumped out the flooded basements, but great injury was done to furniture and personal property. The flood extended over an area of about four blocks.

A $30,000,000 IRRIGATION BOND ISSUE for pushing work being carried on or projected under the U. S. Reclamation Service, is provided for in a bill just introduced in Congress. It is proposed to put the proceeds of this bond issue in a revolving fund, evidently similar to the one built up from the proceeds of public land sales, which has been used to meet the cost of reclamation work thus far.

THE MILEAGE OF RAILWAY TRACKS in the city of Chicago has been ascertained by Mr. Slason Thompson, of the Chicago Bureau of News and Statistics. The total is in excess of 2,500 miles. The details are given in the following table:

Miles of single track (first)	327.26
Miles of second track	299.34
Miles of third track	85.67
Miles of fourth track	56.05
Miles of yard track and sidings	1,448.13
Number of switches	12,083.00
Number of industrial connections	1,545.00
Miles of industrial tracks	278.14
*Total miles of all tracks	2,492.59

*Exclusive of data not received from three minor systems.

These statistics were collected by Mr. Thompson in connection with the current discussion regarding the proposal to compel the electrification of railways within the Chicago city limits. Mr. Thompson estimates, from the experience on the New York City terminal lines, that it would cost at least $400,000,000 to electrify all railway tracks in Chicago. He points out further that the electrification could not be confined to the lines within the city limits, but would have to include all the contiguous territory within the belt lines running from Waukegan around the city to Indiana Harbor. It could not stop short of North Chicago on the north, West Chicago on the west, and Joliet and Blue Island on the south. Mr. Thompson states that the daily railway traffic of Chicago amounts to 116,400 suburban passengers, 23,000 other passengers, and 2,420 freight and passenger trains daily. About 6,000 full car-loads of freight are received and despatched from Chicago, and over 2,000 partially loaded cars. Besides this, there is an enormous traffic of freight cars which pass through the city without breaking bulk.

A MINE FAN INSTALLATION of some interest was recently completed at the mine of the McLean County Coal Co. at Bloomington, Ill. The new installation consists of a 72-in. "Sirocco" double-inlet mine fan, which replaces the old lower-speed fan of about three times that diameter. The old fan had a capacity of 40,000 cu. ft. per min. at a pressure of 2.3 ins. of water and required a 125-HP. engine for driving it. It discharged into a shaft 4 ft. 3 ins. × 8 ft. 9 ins. at the smallest section and 400 ft. deep which led to the first vein of coal. The new fan discharges into this same shaft and thence through a passage extending horizontally about one-half mile into another drop shaft 135 ft. deep leading to the second vein. It is arranged primarily for blowing, but is reversible if occasion demands. The new fan was guaranteed by its manufacturer, the American Blower Co., to deliver 50,000 cu. ft. per min. at a pressure of 3.6 ins. of water on 65 HP. It may later be required to handle 75,000 cu. ft. per min. at 8.1 ins. pressure and is guaranteed to be of ample capacity for such service. The general manager of the mine reports that the new fan is exceeding the guaranteed performance.

HIGH-PRESSURE PINTSCH GAS has been developed by the Safety Car Heating & Lighting Co., of New York City, for transport to places where it is necessary to charge service tanks but where the amounts of gas used do not warrant a generating plant. Gas for such service has previously been transported at the normal storage pressure (14 atmospheres) of the Pintsch lighting systems. In such cases it is possible to recharge the service tanks only by equalizing the pressure between transport and service tanks. Then only some 30% of the gas originally carried in the transport tank was

available for filling and the remainder was left to be returned to the supply station unused. By compressing the gas to 100 atmospheres only about 10% is returned. For filling a given volume of service tanks, a reduction of volume of transport holder to 1/30 that formerly necessary is claimed. The weight of transport holder is reduced to about 1/6 the former.

All liquid hydrocarbons are drained off from ordinary Pintsch gas (at 14 atmospheres) and it is compressed directly into small steel flasks of high tensile strength material. A flask, of 3.75 cu. ft. capacity, weighing about 330 lbs., can be made to hold 500 cu. ft. of free gas. From this it is seen that there is an apparent departure from Boyle's law that the volume varies inversely as the pressure. This is due to a partial condensation in the flasks, but as gas leaves a flask it absorbs the condensed hydrocarbons with no appreciable drop in candle-power value.

In the development of this high-pressure gas, experiments were made with the so-called "Blau gas" which has been called "liquefied Pintsch gas" by many. With this latter, however, certain hydrocarbon liquids have to be added to dissolve that portion of the gas which does not readily condense at heavy pressures. These solvents were found to accumulate in the regulating devices and to clog by freezing in cold weather. The high-pressure Pintsch gas differs from the "Blau gas" then in having present as liquids only the gases which normally condense between 14 and 100 atmospheres.

DELAYS TO PASSENGER TRAINS IN THE STATE of New York are regularly reported to the New York Public Service Commission for the Second District. The report for the month of September, 1909, just issued, shows that of 62,092 trains reported, 82% were on time at their division terminals. It should be stated that passenger trains are considered "on time" if not more than five minutes late. This gives 18% of trains late at division terminals, and the average delay for each late train was 24.3 minutes.

A summary of the principal causes of delay to trains shows that 46.7%, or nearly one-half, were due to waiting for trains on other divisions or for connecting trains on other railways. Nearly 20% were due to train work at stations, and nearly 15% to meeting and passing trains or trains ahead. Signals, by which is probably meant "signals out of order," caused only 1.2% of the delays, and failures of engines or cars and wrecks caused 11%.

Personals.

Mr. Edgar M. Graham, Assoc. M. Am. Soc. C. E., has opened an office at Muskogee, Okla., for practice of general engineering.

Mr. Agnew T. Dice, General Superintendent of the Philadelphia & Reading Ry. and allied companies, has been appointed General Manager. The general superintendency has been abolished.

Mr. S. E. Burkhead, Assistant Division Superintendent of the International & Great Northern R. R. at Palestine, Tex., has resigned that position to enter the service of the Denver & Rio Grande R. R. at Denver, Colo.

Mr. O. H. Ensign, M. Am. Inst. E. E., Chief Electrical Engineer of the U. S. Reclamation Service, has been appointed a member of the advisory board of engineers in charge of construction of the power plants along the Los Angeles Aqueduct. The Los Angeles Board of Public Works has obtained President Taft's permission for Mr. Ensign to serve in this capacity.

Mr. E. J. McCaustland, M. Am. Soc. C. E., Professor of Municipal Engineering at the University of Washington, Seattle, Wash., has been appointed Sanitary Engineer to the Washington State Board of Health. The scope of the powers and duties of this board was recently much enlarged by legislative action, and increased attention will be given to public water-supplies and sewage disposal.

Mr. Cyrus C. Babb, M. Am. Soc. C. E., and recently Project Engineer of the Milk River project, U. S. Reclamation Service in Montana, has severed his connection with the Reclamation Service by transfer to the U. S. Geological Survey. As District Engineer, he will have charge in Maine of cooperative work of the U. S. Geological Survey and the Maine State Water Storage Commission and State Survey Commission.

Mr. C. E. A. Winslow, Assistant Professor of sanitary biology at the Massachusetts Institute of Technology, has been appointed Associate Professor of biology in the College of the City of New York, effective in September, 1910. He has also been made Curator of Public Health in the American Museum of Natural History, New York City. Mr. Winslow will lecture at the University of Chicago in January, February and March, during which time he will be on leave of absence from the Massachusetts Institute of Technology.

Mr. Arthur W. Dean, M. Am. Soc. C. E., State Engineer of New Hampshire, has been appointed Chief Engineer of the Massachusetts Highway Commission, effective Jan. 1. The duties of this newly established position were formerly performed by Mr. Austin B. Fletcher, Secretary of the commission, who has resigned to take a position in California. Mr. Frank I. Bieler, of Boston, Mass., Assistant Secretary of the highway commission, will succeed to the secretaryship, but will divide with Mr. Dean the duties performed by Mr. Fletcher. Mr. Dean is a graduate of the Massachusetts Institute of Technology, class of 1892, and has been State Engineer of New Hampshire since 1904.

Mr. Henry M. Sperry, M. Am. Soc. C. E., Resident Manager of the New York office of the General Railway Signal Co., of Rochester, N. Y., has been made Sales Manager of that company, in charge of the sales and advertising departments and of installation work on contracts. Mr. Sperry will go to Rochester to assume the duties of his new position Jan. 1.

Mr. Sperry has had a wide experience as a signal engineer. He was Supervisor of Signals of the New York division of the Pennsylvania R. R. from 1887 to 1891, and in 1892-4, as General Agent of the Johnson Railroad Signal Co., he had general charge of the block signal system of the New York Central & Hudson River R. R. In 1894-9 he was Signal Engineer and Agent of the National Switch & Signal Co., and in this capacity he designed and constructed the signaling for the elevated railways of Chicago, including that for the union loop. During the period from 1899 to 1905, while Signal Engineer and Agent for the Union Switch & Signal Co., Mr. Sperry prepared plans and a report on the reconstruction of the St. Paul Union Depot, St. Paul, Minn., to provide track facilities for ten railways and also prepared plans for the signaling system of the New York subway.

In 1905-6 he acted as Consulting Signal Engineer for the Hudson & Manhattan R. R. and prepared plans and reports covering the four Hudson River tunnels and the Church St. terminal. Mr. Sperry has been Resident Manager, at New York, for the General Railway Signal Co., since February, 1906.

Obituary.

Horace See, a naval architect of New York City, died Dec. 14 at his home on East 29th St. at the age of 77 years. Mr. See was formerly in the employ of the Wm. Cramp & Sons Ship & Engine Building Co. and was a member of the Society of Naval Architects and Marine Engineers.

Israel W. Morris, Assoc. Am. Inst. M. E., died Dec. 18 at his home in Philadelphia, Pa., aged 80 years. Up to the time of his retirement ten years ago, he was prominent in the development of the anthracite coal fields of Pennsylvania and was President of the Locust Mountain Coal Co. and the Coal Ridge Co.

Gen. J. S. Casement, a civil engineer, died Dec. 13 at his home in Painesville, Ohio. Gen. Casement was born at Geneva, N. Y., in 1829. He was employed in the construction of the Lake Shore & Michigan Southern Ry. from Cleveland, Ohio, to Erie, Pa., and in the construction of the Cleveland, Cincinnati, Chicago & St. Louis Ry. from Cleveland to Columbus, Ohio. In the Civil War he served as a major and later he became a colonel and a brigadier-general. He won considerable distinction during the war for rapid reconstruction of bridges destroyed by the Confederates. After the war, he superintended the construction of a part of the Union Pacific R. R. and subsequently had charge of various other railway construction work.

Julius Bien, President of the firm of Julius Bien & Co., lithographers, died Dec. 21, at his home in New York City. Mr. Bien was born in Hesse-Cassel, Germany, in 1826 and came to the United States when 23 years old. He began business in this country with one lithographic hand press in 1850 and in the course of time became prominent as a specialist in scientific and artistic lithography. He was particularly successful in the reproduction of topographical maps and illustrated the Coast Survey reports, "Atlas and Records of the Rebellion," "Statistical Atlas of United States Censuses," and many other Government and State reports.

Dr. Frank W. Reilly, Assistant Commissioner of Health of Chicago, died Dec. 16. He was born at Bolton, England, in January, 1836, but was brought to this country when a child. He served as a surgeon in the Civil War, and from 1867 to 1873 was a sanitary inspector in the Chicago Health Department. He then entered the U. S. Marine Hospital Service, and was one of the doctors who fought the yellow-fever plague at Memphis, Tenn., being placed afterwards in charge of the sanitary improvement of the city. In 1891 he was appointed member and secretary of the Illinois State Board of Health. In 1891 he became Assistant Commissioner of Health at Chicago, which position he retained until his death. He is credited with inaugurating the publication of the weekly "health bulletin," and was in active charge of much of the aggressive work of the Health Department in its campaign for pure milk, the use of antitoxin in diphtheria and the education of mothers in the poorer districts as to the proper care of babies in order to check the high rate of infant mortality.

Dr. Charles B. Dudley died at Altoona, Pa., on Dec. 21, after a brief illness of typhoid pneumonia. Hardly a man in the American engineering profession was more widely known and more universally respected than Mr. Dudley. He was born in Chenango County, N. Y., July 14, 1842, and was educated at the country schools and the village academy. He enlisted in the army in 1862 and served until the close of the war, when he resumed his studies and finally graduated from Yale in the class of 1871. He followed this up with a post-graduate course in the Sheffield Scientific School, from which he graduated in 1874. Only a year after his graduation he was appointed chemist of the Pennsylvania R. R. Co. with offices at its mechanical headquarters in Altoona, and this position he held throughout his life.

While Dr. Dudley was primarily a chemist, his work brought him in touch with a large range of engineering activities, and he became well known throughout engineering circles. In practical original research leading to industrial developments he bore a foremost part, and he received high honors from the scientific and engineering societies with which he was connected. He was twice chosen President of the American Chemical Society, has been a Vice-President of the American Institute of Mining Engineers, and has been a member of the other three national engineering societies of America, as well as a member of the principal chemical and metallurgical societies abroad. As President for several successive years of the American Society for Testing Materials he has done a large service to the profession in furthering the prosperity of that organization. This year he was also elected President of the International Society for Testing Materials.

In personal qualities Dr. Dudley was a man of the most genial and sunny disposition. He went through life making friends at every turn, and even those whom he had to oppose in his professional work were compelled to respect and honor his fairness and friendliness. A few years ago the Pennsylvania R. R. Co., in view of Dr. Dudley's long and valuable services, relieved him of the official responsibilities he had so long carried, so that he has had liberty to carry on such work as he chose and enjoy foreign travel. In our issue of Jan. 28, 1904, at the time of Dr. Dudley's election to the presidency of the American Society for Testing Materials, we published a portrait and full biography of Dr. Dudley. That biography closed with the sentence "Dr. Dudley has never married." It is pleasant for his friends who appreciate his sweet and lovable disposition to know that not long after that time Dr. Dudley was very happily married, so that the last years of his life were made pleasant in the comfort of his own home.

Engineering Societies.

COMING MEETINGS.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.
Dec. 27-Jan. 1. Annual meeting at Boston, Mass. Secy., L. O. Howard, Smithsonian Institution, Washington, D. C.

AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS.
Dec. 28-29. Annual meeting at Ames, Iowa. Secy., L. W. Chase, University of Nebraska, Lincoln, Neb.

MONTANA SOCIETY OF ENGINEERS.
Jan. 6-8. Annual meeting at Butte, Mont. Secy., Clinton H. Moore, Butte, Mont.

MICHIGAN ENGINEERING SOCIETY.
Jan. 12-14. Annual meeting at Lansing, Mich. Secy., Alba L. Holmes, 574 Wealthy Ave., Grand Rapids, Mich.

INDIANA ENGINEERING SOCIETY.
Jan. 13-15. Annual convention at Indianapolis, Ind. Secy., Chas. Brossmann, Union Trust Bldg., Indianapolis, Ind.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS.
Jan. 18-20. Annual meeting at New York City. Secy., W. M. Mackay, P. O. Box 1818, New York City.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
Jan. 19-20. Annual meeting at New York City. Secy., Chas. W. Hunt, 220 West 57th St., New York City.

AMERICAN SOCIETY OF INSPECTORS OF PLUMBING AND SANITARY ENGINEERS.
Jan. 20-22. Annual convention at Trenton, N. J. Secy., C. S. McCosker, Mobile, Ala.

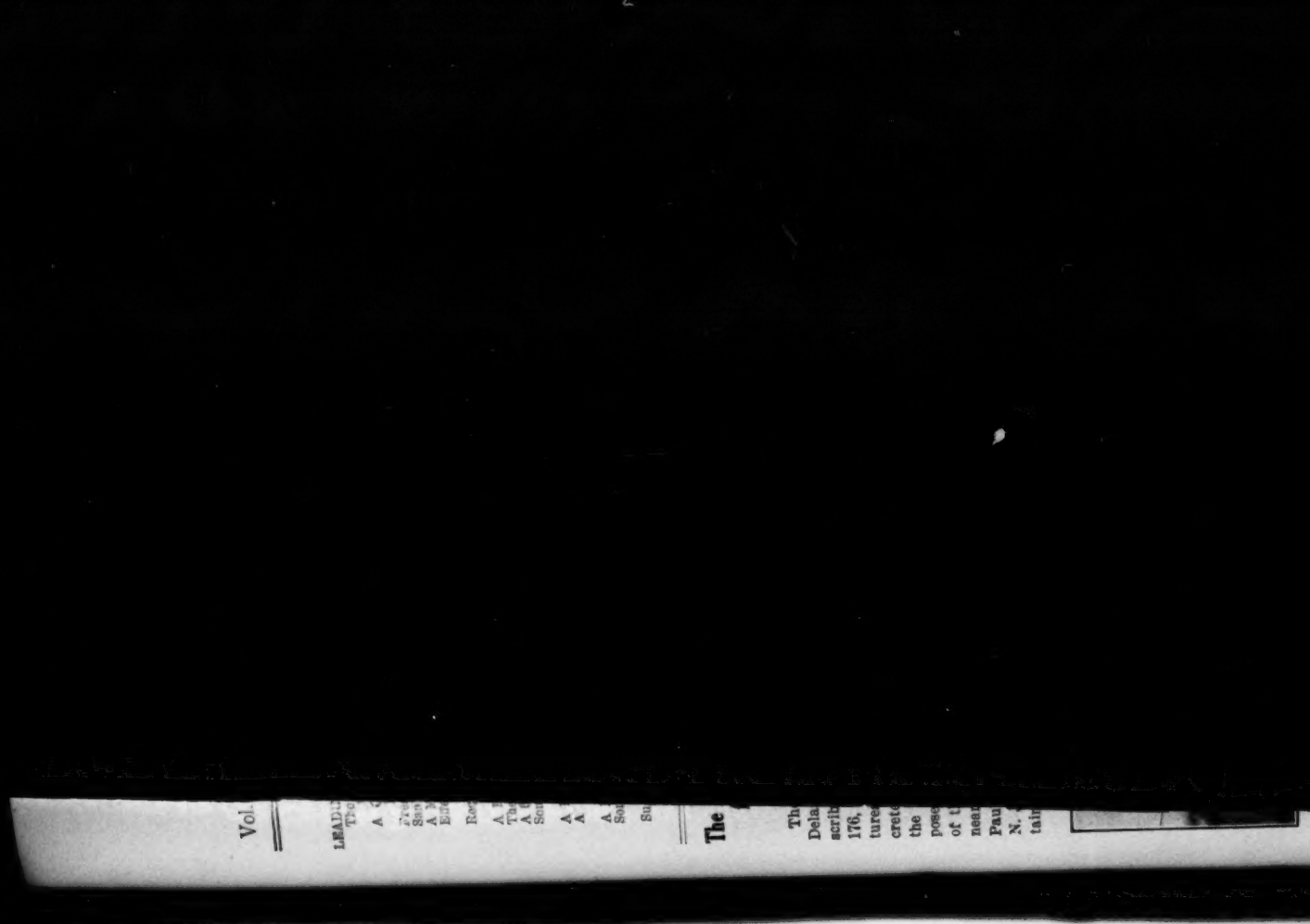
CANADIAN SOCIETY OF CIVIL ENGINEERS.
Jan. 25-27. Annual meeting at Ottawa, Ont. Secy., C. H. McLeod, 413 Dorchester St. West, Montreal, Que.

ILLINOIS SOCIETY OF ENGINEERS AND SURVEYORS.
Jan. 26-28. Annual meeting at Cairo, Ill. Secy., E. E. R. Tratman, 1636 Monadnock Block, Chicago, Ill.

NATIONAL BRICK MANUFACTURER'S ASSOCIATION.
Feb. 7-12. Annual convention at Pittsburg, Pa. Secy., T. A. Randall, Indianapolis, Ind.

CONNECTICUT SOCIETY OF CIVIL ENGINEERS.
Feb. 8. Annual meeting at New Haven, Conn. Secy., J. Frederick Jackson, Box 1304, New Haven, Conn.

NEW ENGLAND ASSOCIATION OF GAS ENGINEERS.
Feb. 16. Annual meeting at Boston, Mass. Secy., N. W. Gifford, 26 Central Square, E. Boston, Mass.

IOWA ENGINEERING SOCIETY.
Feb. 16-17. Annual convention at Cedar Rapids, Iowa. Secy., A. H. Ford, Iowa City, Iowa.

NATIONAL ASSOCIATION OF CEMENT USERS.
Feb. 21-26. Annual convention at Chicago, Ill. Pres., Richard L. Humphrey, Harrison Bldg., Philadelphia, Pa.